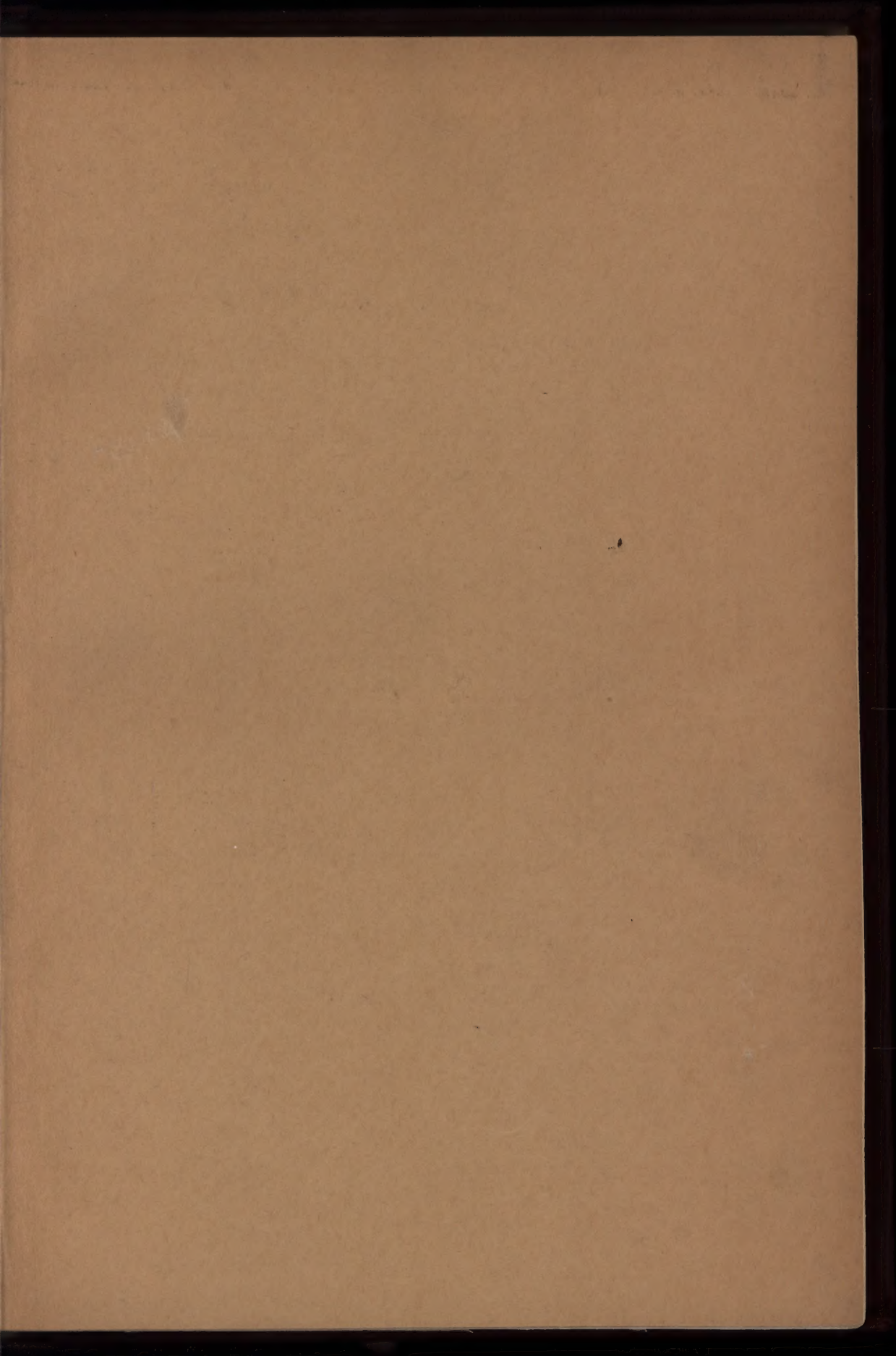




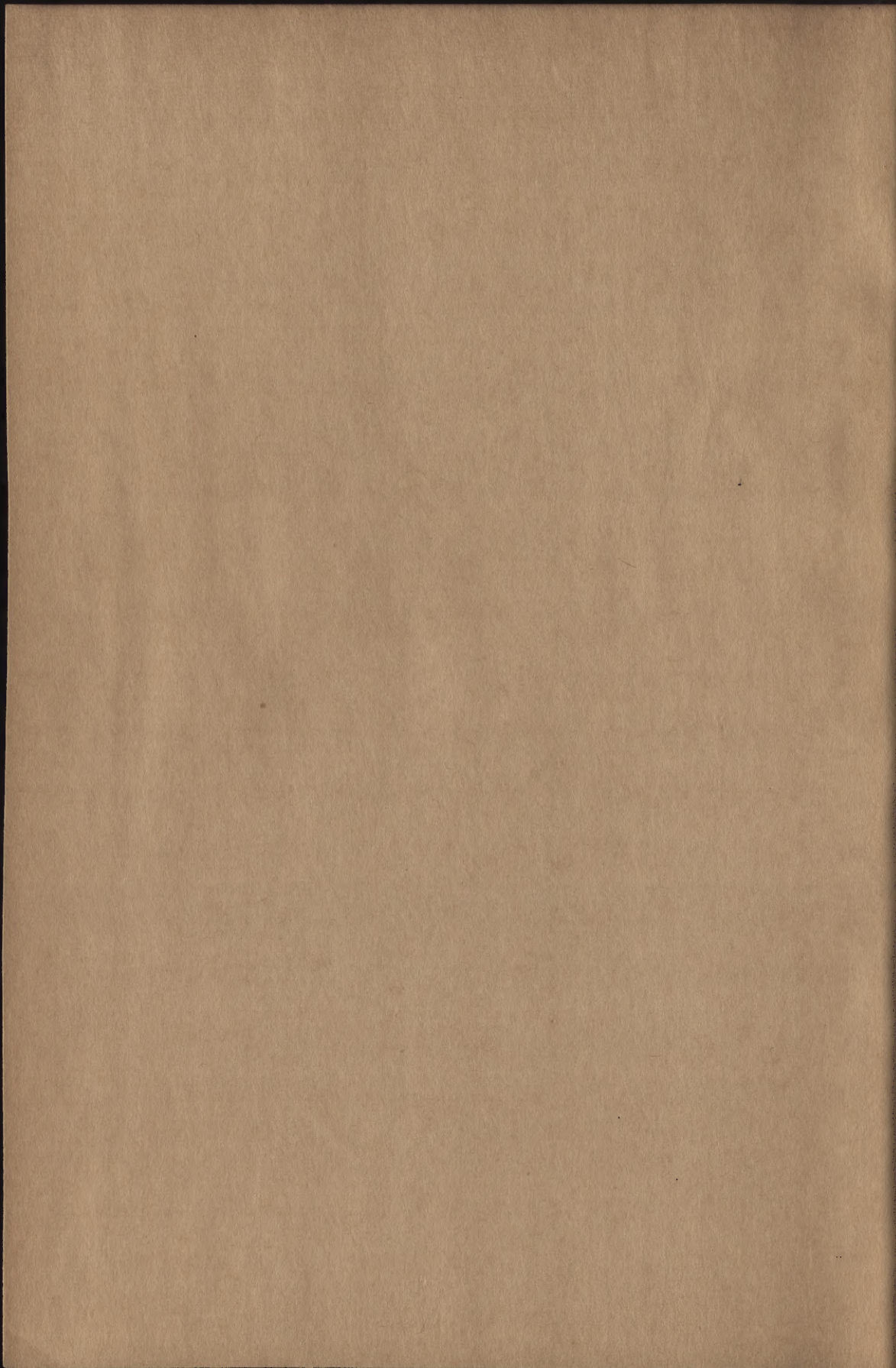




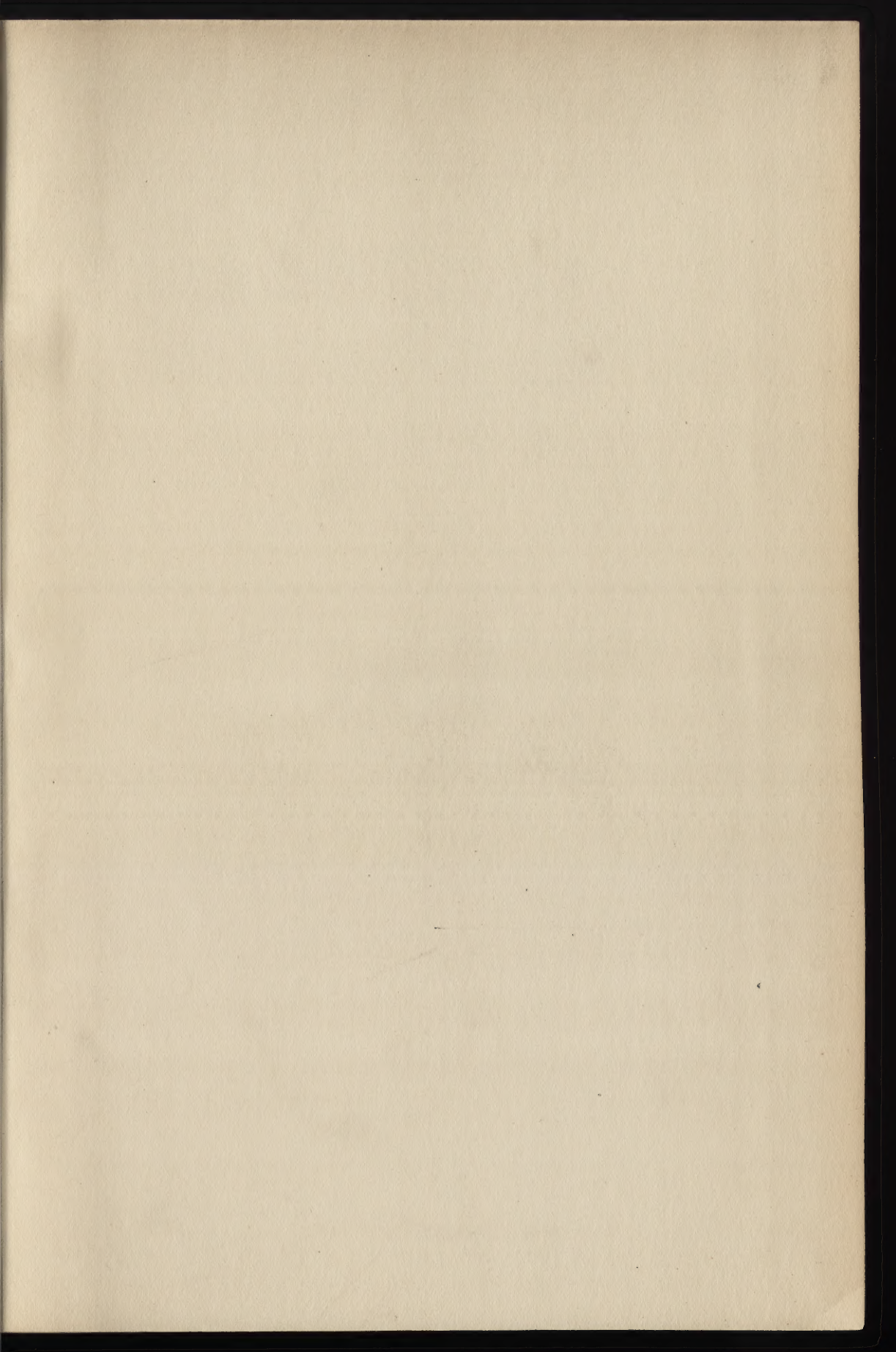
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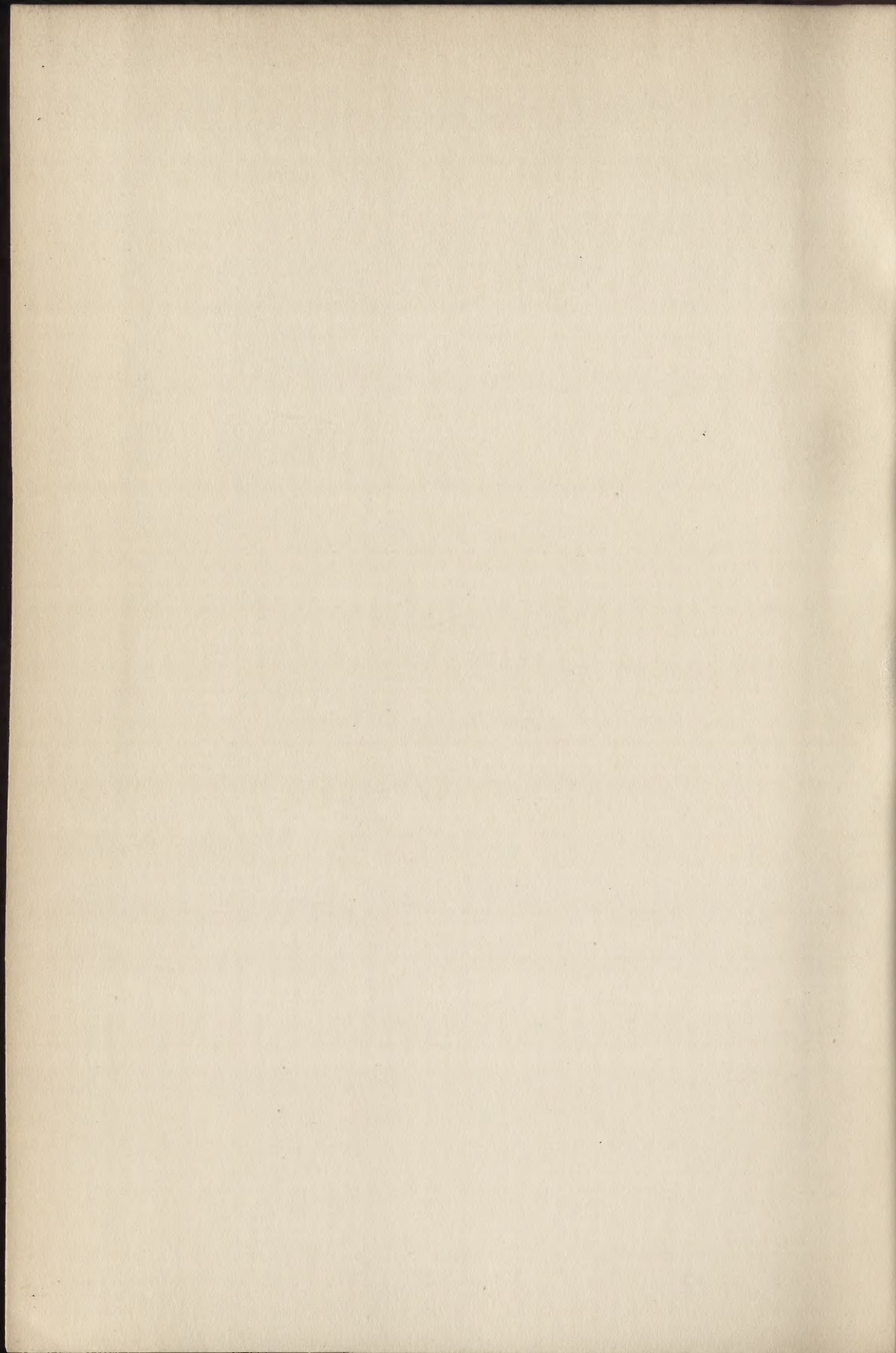




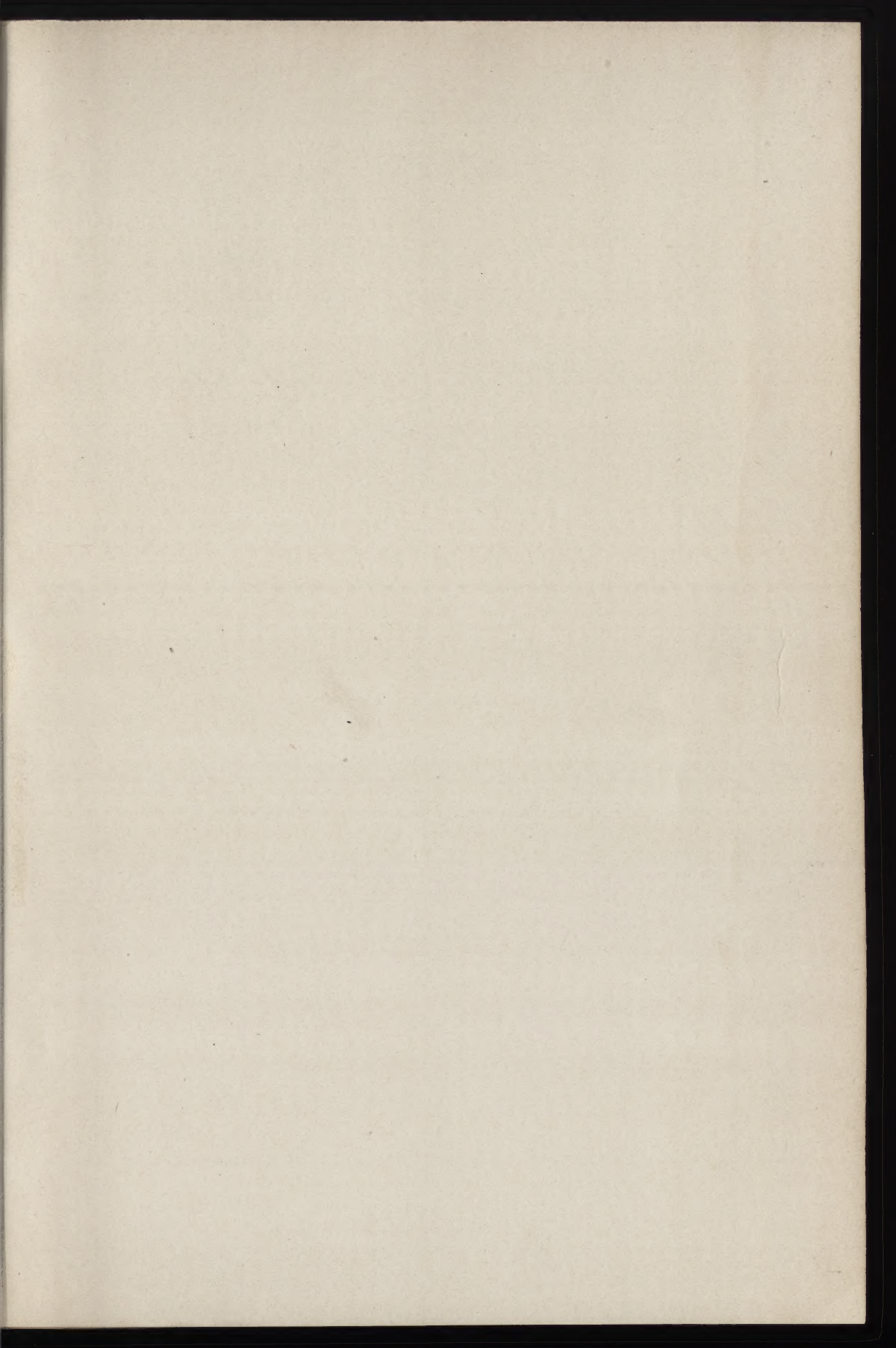


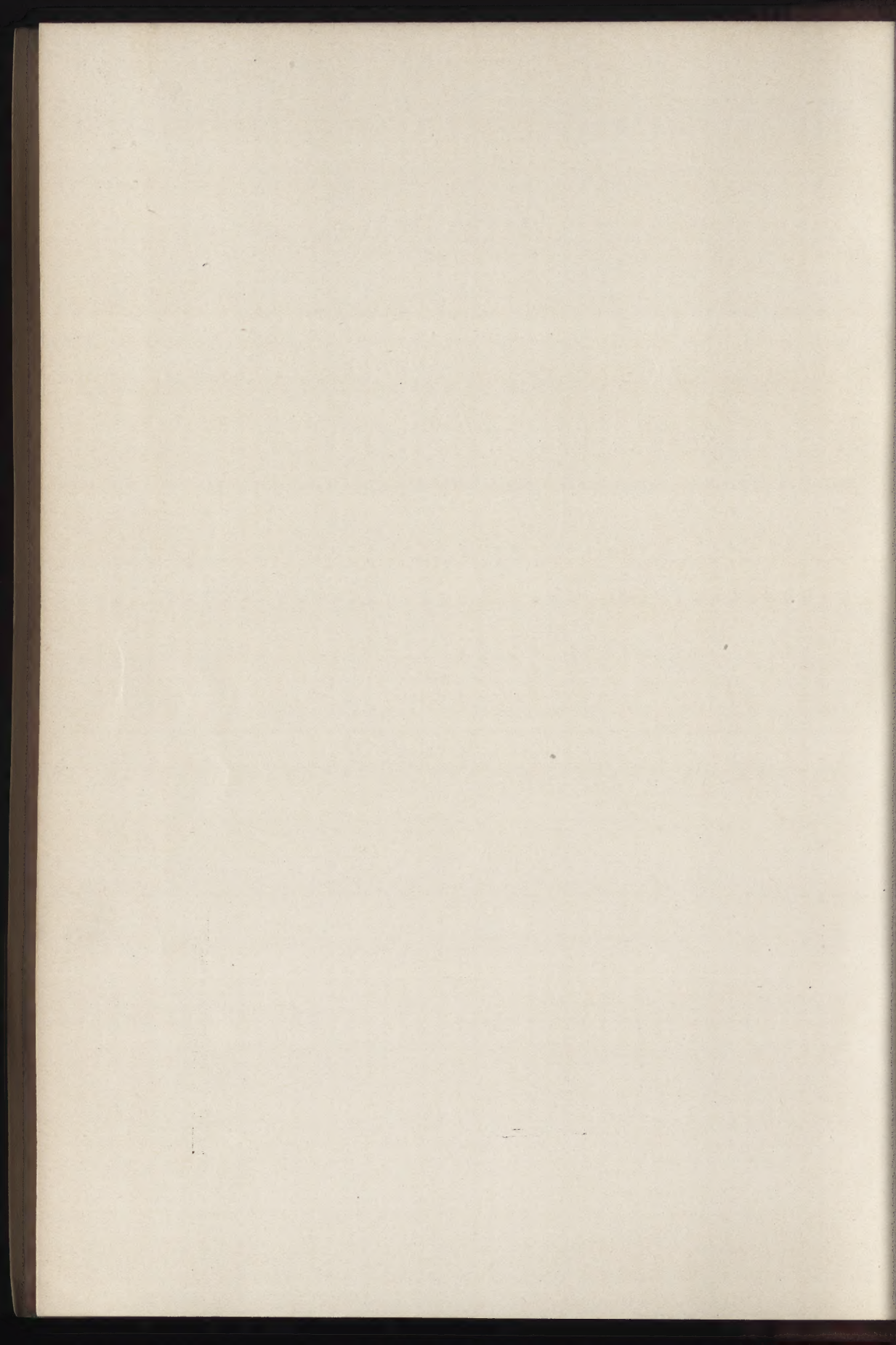








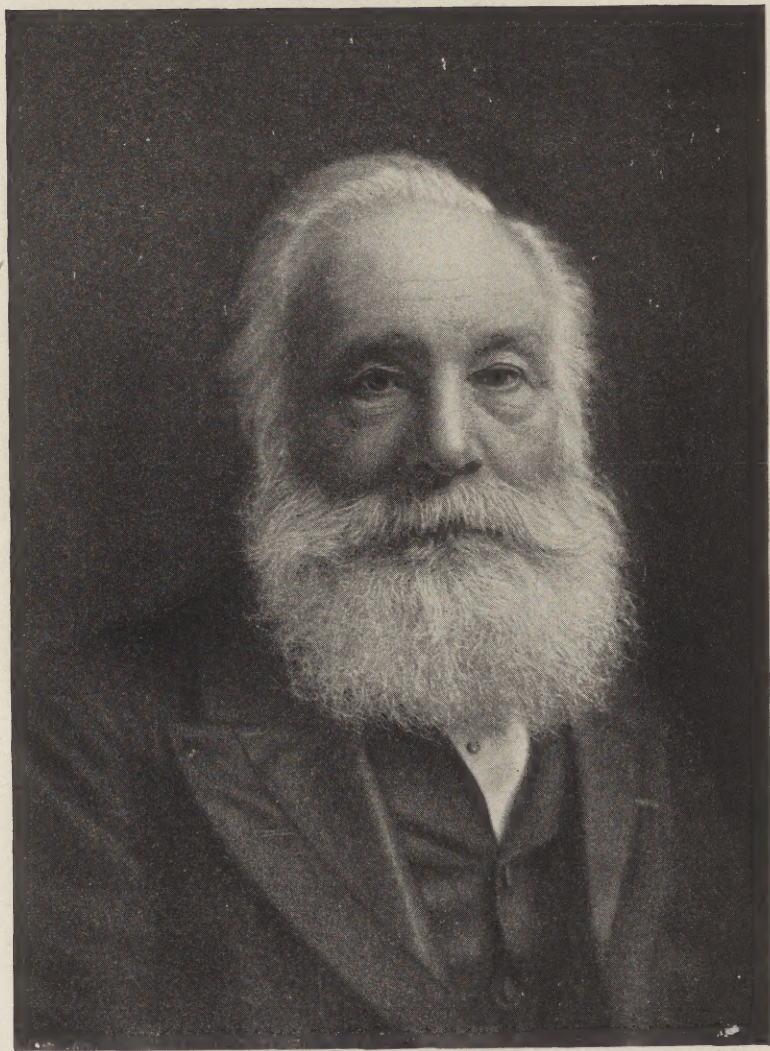












SIR WILLIAM HENRY PERKIN

Discoverer of Mauve, the First Coal Tar Coloring Matter



# Cyclopedia *of* Textile Work

*A General Reference Library*

ON COTTON, WOOLEN AND WORSTED YARN MANUFACTURE, WEAVING, DESIGN-  
ING, CHEMISTRY AND DYEING, FINISHING, KNITTING,  
AND ALLIED SUBJECTS.

*Prepared by a Corps of*

TEXTILE EXPERTS AND LEADING MANUFACTURERS

*Illustrated with over Two Thousand Engravings*

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THE editors have freely consulted the standard technical literature of Europe and America in the preparation of these volumes and desire to express their indebtedness, particularly to the following eminent authorities, whose well known treatises should be in the library of every one connected with textile manufacturing.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost manufacturers of textile machinery, in making these volumes thoroughly representative of the best and latest practice in the design and construction of textile appliances; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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## Introductory Note

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**T**HE Cyclopedia of Textile Work is compiled from the most practical and comprehensive instruction papers of the American School of Correspondence. It is intended to furnish instruction to those who cannot take a correspondence course, in the same manner as the American School of Correspondence affords instruction to those who cannot attend a resident textile school.

**T**he instruction papers forming the Cyclopedia have been prepared especially for home study by acknowledged authorities, and represent the most careful study of practical needs and conditions. Although primarily intended for correspondence study they are used as text-books by the Lowell Textile School, the Textile Department of the Clemson Agricultural College, the Textile Department of the North Carolina College of Agriculture and Mechanic Arts, the Mississippi Textile School, and for reference in the leading libraries and mills.

**Y**ears of experience in the mill, laboratory and class room have been required in the preparation of the various sections of the Cyclopedia. Each section has been tested by actual use for its practical value to the man who desires to know the latest and best practice from the card room to the finishing department.

¶ Numerous examples for practice are inserted at intervals. These, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a textbook with a reference work.

¶ Grateful acknowledgment is due to the corps of authors and collaborators, who have prepared the many sections of this work. The hearty co-operation of these men — manufacturers and educators of wide practical experience and acknowledged ability — has alone made these volumes possible.

¶ The Cyclopedia has been compiled with the idea of making it a work thoroughly technical, yet easily comprehended by the man who has but little time in which to acquaint himself with the fundamental branches of textile manufacturing. If, therefore, it should benefit any of the large number of workers who need, yet lack, technical training, the editors will feel that its mission has been accomplished.





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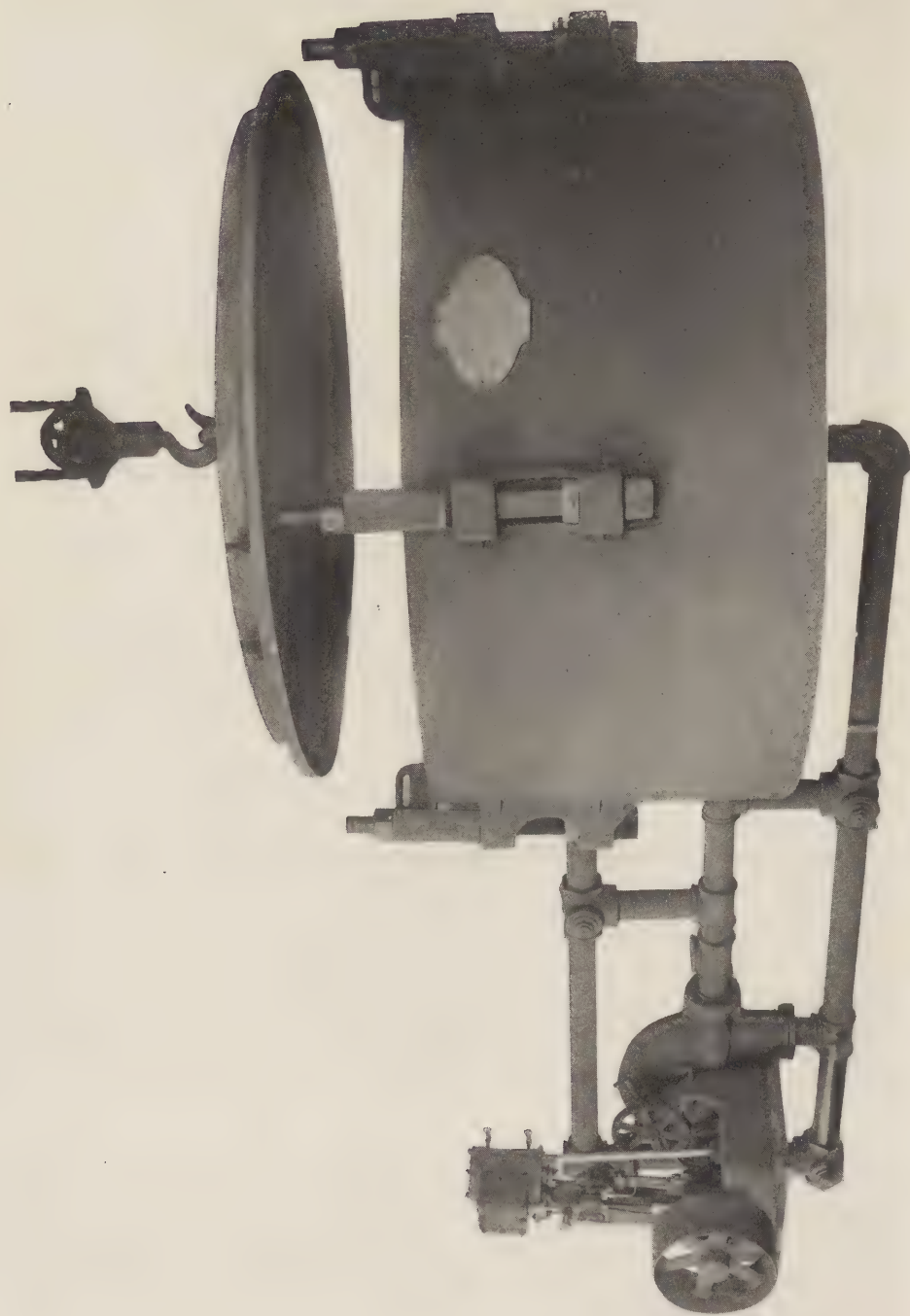
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IMPROVED VACUUM DYEING MACHINE WITH CAST IRON BOWL AND PLATES

Vacuum Dyeing Machine Co.



# CHEMISTRY AND DYEING.

## TEXTILE CHEMISTRY AND DYEING.

1. One needs but a limited knowledge of the subject of textile coloring to readily see that, no matter how much the numerous processes may differ in principle or vary in detail, they all involve two fundamental factors.

First: The Material to be colored.

Second: The Substances to be used as coloring agents.

2. To acquire a knowledge of the first, one must carefully study the chemical and physical properties of the various fibres together with their action toward the different chemicals with which they may come in contact during the process of manufacture, and the subsequent dyeing and finishing. A thorough knowledge of the second is necessary to the dyer, but it is only when this knowledge is combined with a thorough acquaintance with the first that proficiency is attained in the art of textile coloring.

3. A thorough conception of these factors can be obtained only after a careful preliminary study of Chemistry, and when thus prepared the student is ready to take up the Study of Textile Chemistry and Dyeing, which should include the following subjects:

1. Technology of the Fibres.
2. Operations Preliminary to Dyeing.
3. Water and its Application in the Textile Industry.
4. Mordants and other Chemical Compounds used in the Textile Industry.
5. Theories of Dyeing.
6. Natural Coloring Matters.
7. Artificial Coloring Matters.
8. Machines used in Dyeing.

## TECHNOLOGY OF FIBRES.

4. For convenience, fibres are divided according to their origin into the following classes:

- |               |                |
|---------------|----------------|
| 1. Vegetable. | 3. Mineral.    |
| 2. Animal.    | 4. Artificial. |

The third class, however, is of minor importance in the Textile Industry.

**5. Members of Each Class.** Of *vegetable fibres*, cotton is by far the most important, then follows linen, hemp, jute, China Grass, or ramie, and a few others of less importance, such as Manilla hemp, Sunn hemp, New Zealand flax and the fibre obtained from various palms.

The other vegetable substances with which the dyer may have to deal are straw for hats, vegetable ivory used for buttons, wood fibre, and paper pulp which may consist of almost any vegetable fibre or mixture of vegetable fibres.

The only *animal fibres* of great importance are wool, and a few varieties of hair, and silk. To this class also belong such substances as leather, feathers, horn and bone, all of which are sometimes colored.

Under the head of *mineral fibres* are included such substances as glass wool, slag wool, asbestos, etc. These are used in certain chemical operations, and in covering steam-pipes, boilers, steam-jacketed kettles and stills, on account of being non-conductors of heat, but for practical purposes they are never colored, and need not be further considered.

Under the head of *artificial fibres* are included all fibres produced artificially from chemical products. The only one of importance, however, is artificial silk, and this will be considered later. (See Art. 24.)

### COTTON.

6. Cotton is the downy, fibrous material that covers the seeds of several species of plants known botanically as *Gossypium*. The fibre and seeds are enclosed in a three to five valved capsule or cotton boll, which when ripe bursts open. The cotton is then picked and separated from the seeds by a process known as ginning, the products being cotton, ready to be baled, and cotton seed.

**7. Cotton Seed Industry.** Formerly, cotton seeds had no commercial value, but in recent years they have become a source of great income, owing to the large amount of oil which can be pressed from them, and also for the various animal feeding

products obtained therefrom. Certain portions of the seeds are also valuable as fertilizers.

Considering the annual product of the United States as 10,000,000 bales of cotton, the corresponding amount of seed is 5,000,000 tons, with an average value of \$10 a ton as a raw product.

**8. Motes.** The complete removal of the fine particles of broken seed from the fibre is not always possible, and they are visible in the unbleached cloth as small specks, technically known as motes.

**9.** Under certain conditions these motes give up a portion of the tannic acid which they contain. Tannic acid has a great affinity for some dyestuffs (particularly that class known as basic colors), and unless these motes are completely removed from the cloth before the dyeing, it is likely that more color will be deposited in their immediate neighborhood than on any other portions of the cloth, thus producing dark spots and uneven dyeing.

**10.** A typical cotton fibre is a long tubular vegetable cell varying in diameter from .0004 to .001 of an inch, and from .75 to 1.5, and in extreme cases nearly 2 inches in length. (See Fig. 1.)

When examined under the microscope, matured cotton fibres present the appearance of long flattened tubes, thicker at the edge than at the center, and spirally twisted, thus resembling a twisted ribbon, the edges of which are thick and rounded. This spirally twisted appearance is most marked in fully ripened fibres and is probably due to the drying and contraction of the sap which fills the central opening of the partially ripened fibre.

In cross-section, cotton fibres present a variety of shapes, as shown in Fig. 2, but all have the appearance of flattened tubes

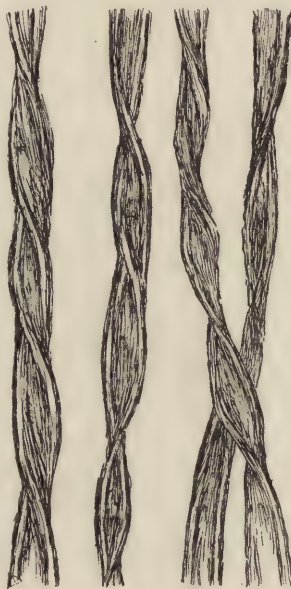


Fig. 1.



with comparatively thick walls and a small central opening. This opening runs from the end of the fibre attached to the seed almost to the opposite end, which appears to be closed.

It is the special character of the fibre which renders it suitable for the manufacture of very fine yarns. Its hollow and twisted condition makes it light and elastic as compared with linen, which, although having a longer fibre, is stiff and straight.

11. The value of the microscope in the detection and examination of the various fibres cannot be overestimated, and when used in conjunction



Fig. 2.

with various chemical tests it is, in most cases, an easy matter to identify the various fibres, and also the constituent fibres of mixed material.

12. **Dead Fibres.** Under microscopic examination one often finds cotton fibres which present no indication of a hollow central opening but on the contrary show a broad ribbon-like structure, almost transparent and with irregular folds. (Fig. 3.) These are



Fig. 3.

young or unripe fibres, technically known as *dead fibres*. They are very difficult to dye as compared with ripe cotton fibres, and with certain colors, especially indigo and alizarine, may appear in the dyed material as white specks.

13. The principal substance of cotton fibre is cellulose, and the remainder chiefly water and certain natural impurities.

The approximate composition may be given as follows,

Cellulose	87 to 90 per cent.
Water	5 to 7 per cent.
Natural Impurities	4 to 6 per cent.

14. **Cellulose** constitutes the foundation or frame work of plant life, but in most cases it is accompanied by a large proportion of resinous material, coloring matter, dried sap, etc. It occurs in cotton in a comparatively pure state.

Considered chemically, it has a formula,  $C_6H_{10}O_5$ , and belongs to the class of organic compounds known as the carbohydrates. It is, when pure, a snowy white solid substance, insol-

uble in ordinary solvents, such as water, alcohol and ether, but dissolves in concentrated sulphuric acid and also in an ammoniacal solution of cupric hydrate, known as Schweitzer's Reagent, from which it is precipitated by acids.

**15. Hygroscopic Moisture.** The moisture present in raw cotton is of hygroscopic nature, and this is the reason why the percentage may vary to such an extent.

By hygroscopic moisture we mean moisture that is not chemically combined as a constituent of the main substance of any material, but mechanically held in its pores. Hygroscopic substances are usually more or less porous. A hygroscopic substance, when placed in a very dry atmosphere, will gradually give up its moisture, and if heated any length of time to a temperature just above the boiling point of water, it will be almost entirely removed. By application of this principle it is possible to determine the percentage of moisture in the various fibres. This will be discussed more fully under Silk, which is a very hygroscopic fibre.

On the other hand, if a hygroscopic substance is placed in a very moist atmosphere it will absorb moisture and increase in weight. Thus certain fibres, more particularly animal fibres, if stored in a damp place will contain a higher percentage of moisture than when stored in a very dry place.

**16. Natural Impurities.** Investigations that have been made in regard to the natural impurities of cotton indicate at least five different constituents, enumerated as follows :

(1) A waxlike body, commonly known as *cotton wax*, which is insoluble in, and lighter than water, and having a comparatively high melting point. The fact that raw cotton or material made of raw cotton is so difficult to saturate with water or wet out, is probably due to a thin but impenetrable coating of this wax upon the surface of the fibre.

(2) A fatty matter that melts at  $55^{\circ}\text{C}$  and appears to be either margaric acid or a mixture of palmitic and stearic acids.

(3) Certain nitrogenous, non-crystalline coloring matters of a brownish color.

(4) A light amorphous substance of an acid character, resembling certain gums and known as *pectic acid*.

(5) Albuminous matter in small quantities.

Of the five constituents mentioned above, the pectic acid is present in the largest proportion, the coloring matters next, while the others are present in very small quantities.

**17. Bleaching.** The chief object of bleaching cotton is to remove the natural impurities and coloring matters, and to leave the fibre as nearly pure cellulose as possible. This, however, will be discussed in detail under that head.

**18. Absorbent Cotton.** By successively treating cotton with various solvents, such as alcohol, ether, etc., it is possible to remove from cotton the last traces of impurities and leave behind, except for the moisture it may contain, practically pure cellulose. This is known as absorbent cotton, and is largely used in surgery.

#### ACTION OF COTTON TOWARD ATMOSPHERIC CHANGES AND CHEMICAL REAGENTS.

**19. Mildew.** Cotton material that is contaminated with organic matter, such as starch, gum, etc. (for instance, finished calicoes, or any heavily sized cotton cloth, particularly if stored in a warm, moist atmosphere), is likely to be acted upon by a certain low order of vegetable organism or mold, known as mildew. A sort of fermentation of the sizing material sets in, and eventually the fibre itself is attacked and becomes tendered.

Little trouble, however, is experienced with raw cotton, and even less with bleached cotton, owing to the comparative freedom from impurities.

**20. Frost.** No definite information can be given in regard to the action of frost on cotton fibre and material. It has been thought by some that cotton, being hollow, would, if cooled below the freezing point, when in a moist condition, become stiffened by the formation of a core of ice, and when handled in this condition become easily broken.

**21. Acids.** The action of various acids on cotton is an extremely important consideration, for under certain conditions many of the acids used in the various textile processes will seriously affect, and in some cases entirely destroy the fibre.

In general, concentrated mineral acids will seriously corrode, and in many cases completely destroy cotton fibre, the results



varying according to the nature of the acid, its degree of concentration and the temperature.

Cold dilute mineral acids have little or no action on cotton if the last traces are washed out, but if allowed to dry on the fibre they gradually become sufficiently concentrated to corrode and tender it, and in some cases bring about complete destruction.

If the acid action is not too energetic, the physical appearance of the fibre is scarcely altered, but a change in chemical composition takes place. The cellulose is converted more or less completely into a substance chemically known as oxy-cellulose. When completely converted into oxy-cellulose, the fibre has no strength, and when subjected to the least friction or mechanical agitation is reduced to a grayish powder. Upon this fact depends the process of carbonization.

**22. Sulphuric Acid.** When brought in contact with concentrated sulphuric acid, cotton fibre swells into a gelatinous mass, the cellulose being converted into a substance known as amyloid.

This fact is utilized in the preparation of *artificial parchment*. Paper is composed chiefly of cellulose. Heavy unsized paper is passed into cold concentrated sulphuric acid for a few seconds, which converts the surface into this substance called amyloid. The surface then becomes more compact, and when washed and dried is extremely hard. The result is a good imitation of natural parchment.

Warm concentrated sulphuric acid completely dissolves cotton, converting the cellulose into a soluble substance known as *dextrin* or *British gum*.

Hot dilute sulphuric acid is likely to tender cotton, if it comes in contact with it any length of time, but cold dilute sulphuric acid has no perceptible action unless the fibre is dried before the acid is washed out.

**23. Nitric Acid.** The action of nitric acid on cotton is of extreme importance, since through its action many valuable articles, such as gun-cotton, celluloid and artificial silk, are produced.

When heated with concentrated nitric acid, cotton is entirely decomposed, producing oxy-cellulose and oxalic acid, but when acted upon by cold concentrated nitric acid, or, better, a cold

mixture of nitric and sulphuric acid, the cellulose of the cotton is changed into nitro-cellulose.

Depending on the strength of the acid and length of duration of the action, different products may be formed, such as

$C_{12}H_{16}(NO_3)_4O_6$	Tetra Nitro-cellulose.
$C_{12}H_{15}(NO_3)_5O_5$	Penta Nitro-cellulose.
$C_{12}H_{14}(NO_3)_6O_4$	Hexa Nitro-cellulose.

The first two are soluble in alcohol and ether, and are known as soluble gun-cotton. Such a solution is known as collodion and is largely used for photographic and other purposes. Gun-cotton is also known as pyroxylin.

The Hexa nitro-cellulose is insoluble in alcohol and ether, and is a violent explosive and a constituent of many modern explosives.

The other cellulose nitrates are explosive, but not to as great an extent as the Hexa products.

*Celluloid* is made by properly mixing soluble gun-cotton with camphor.

*Artificial silk* is made from soluble gun-cotton.

Dilute nitric acid has little if any action on cotton if thoroughly washed from the fibre, but if allowed to dry upon the fibre it gradually becomes concentrated enough to convert the cotton into oxy-cellulose.

**24. Artificial Silk.** Several different processes, and many modifications of these processes, have been tried, having as the object the production of artificial silk, but the majority have proved of no practical value.

The oldest and probably most successful is the one introduced by Chardonnet in 1884. The principle of this process depends upon the fact that a solution of Tetra nitro-cellulose solidifies when brought into contact with cold water. This solution of Tetra nitro-cellulose, commonly known as pyroxylin, is forced, under pressure, through a tube A, (Fig. 4), which ends in a very fine capillary orifice O. The inner tube A is surrounded by an outer tube T, through which there is a constant flow of cold water. Upon coming in contact with the cold water at O the pyroxylin solidifies and can be drawn out, dried and reeled in the form of a continuous fibre.

When made from pure pyroxylin the fibre is so inflammable as to be extremely dangerous. In order to reduce its great inflammability, certain metallic chlorides may be added to the pyroxylin solution, and sometimes the fibre is treated with ammonium phosphate. Colored effects are often produced by adding the proper dyestuffs directly to the pyroxylin solution. In brilliancy artificial silk even surpasses the natural.

Its use is limited to cases where great durability is not essential and where it is not likely to come in contact with water. It is said that the demand is greater than the supply, and that in some cases it brings a price greater than some grades of silk.

**25. Hydrochloric Acid.** Hydrochloric acid, whether concentrated or dilute, has the mildest action on cotton of any of the so-called mineral acids, but if allowed to dry upon the fibre tendering follows, and if dried at a high temperature the fibre is completely disintegrated.

**26. Other Acids.** Phosphoric acid acts similarly to hydrochloric acid.

Acetic acid has no noticeable action on cotton.

Solutions of oxalic, tartaric, and citric acids have no apparent action, but if the cotton is saturated with a 2 per cent solution of these acids, and dried at 100° C. for an hour, it becomes slightly tendered, and when saturated with a 5 per cent solution and dried for an hour at 100° C., there is a decided destructive action. If, however, the acids are mixed with certain thickening agents, such as starch, gum, etc., and the dry heat replaced by steaming, there is little fear of serious tendering. These facts are of importance since in the production of calico prints it is sometimes necessary to use as high as 3 to 4 per cent of these acids in a printing paste.

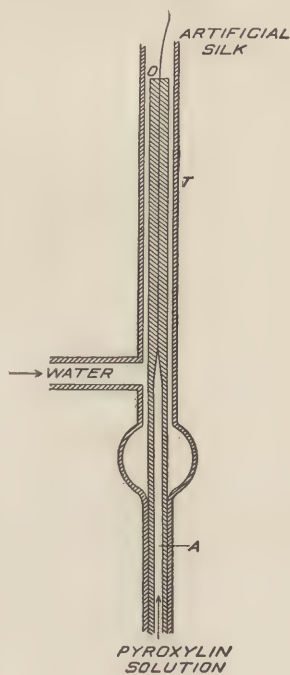


Fig. 4.



**27. Alkalies.** The action of alkalies on cellulose, and consequently on the vegetable fibres, is entirely different from that of acids.

The alkaline carbonates, including the carbonates of potassium, sodium and ammonium, borax and soap, have no action under ordinary conditions. Dilute caustic alkalies, and lime water even at a boiling temperature do not tender cotton fibre if air be entirely excluded, but if allowed to come in contact with the air at this high temperature the oxygen gradually converts the cellulose into oxy-cellulose, thus greatly reducing the strength or even destroying the fibre.

#### MERCERIZATION.

**28.** The action of strong caustic soda, or caustic potash solution, on cotton is not only remarkable, but the practical application of this action has proved of great interest and value to the textile industry.

If a piece of cotton cloth is steeped for a few minutes in a solution of caustic soda ( $50^{\circ}$  to  $60^{\circ}$  \* Tw. Sp. Gr. 1.25 to 1.30), it assumes a gelatinous appearance, and when taken out and washed it is found to have shrunk considerably in surface area, and become of much closer texture.

Should a single fibre of this cloth be examined under the microscope it will be found to have lost the appearance of a perfectly normal cotton fibre. The



Fig. 5.

spirally twisted appearance has disappeared and it has no superficial markings, but has become

thick, straight, rod-shaped and transparent. (See Fig. 5.) The sectional appearance is entirely changed also. It has no longer the appearance of a flattened tube, but is cylindrical, while its walls have thickened until the central opening has become a mere point.

Cotton treated in this way not only increases in strength, but has a greater attraction for coloring matters.

This peculiar action of caustic soda was discovered by John

\* NOTE. To find the specific gravity or density of liquids, hydrometers are used. There are various forms such, as Baumé, Twaddle, etc. The Twaddle (abbreviated to Tw.) is used for liquids denser than water. This subject will be taken up later. (See page 39.)

Mercer, a Lancashire calico printer, more than fifty years ago, while attempting to filter a concentrated caustic soda solution through a piece of cotton cloth. Later he patented a process for treating cotton cloth with caustic soda, and hence the term mercerization.

Mercer's process consisted in simply passing the cloth through a caustic soda solution, when the action already mentioned took place. The results were that cloth counting 200 threads to the inch would become so compact as to count 270. The increase in strength for a given width was 50 per cent, or even more, and a given amount of cloth would increase in weight 4.5 to 5.5 per cent. It also assumed a finer superficial appearance, and an increased lustre, and affinity for dyestuffs.

At one time it was thought that an application of this process to cotton cloth would be of great value to the textile industry, as will be seen by the fact that Mercer was offered \$200,000 for his patent in 1852, which he refused to accept. The cloth, however, shrank from 20 to 25 per cent in length as well as in width, and this, together with the fact that its increase in durability would tend to make the call for fresh supplies less often, led to its abandonment.

It has proved of value for other purposes, and the principal use at the present time, and undoubtedly the most important application ever made, is in the production of a silk-like gloss on cotton yarn by mercerizing it in such a way that it cannot shrink.

It is still an open question, in this country at least, as to the legal claimant to the process of producing lustre on yarn by mercerization. The most aggressive claimants are Horace Arthur Lowe, who took out certain patents about 1891, and Thomas and Prevost, who took out others in 1895.

The various processes for obtaining this silky lustre differ mechanically in the method of preventing the shrinkage, but the general principles involved are the same in all, and are as follows:

The mercerizing bath consists of a caustic soda solution kept commonly at a Sp. G. between 50° and 60° Tw.

Solutions of a Sp. G. less than 15° Tw. have but slight mercerizing action. For the best results the temperature should remain low, about 15° C. and not over 20° C.

The time of immersion is of little consequence as long as the yarn is thoroughly saturated. Ten minutes is usually long enough. The yarn is commonly under tension when it enters the mercerizing bath, but in some methods it is subjected to tension upon being taken from the bath. In either case, however, it is necessary that the lye be washed from the yarn before the tension is relieved.

Although all cotton receives a silky lustre upon mercerization under tension, up to the present time it is only long staple cotton, such as Egyptian and Sea Island, that appears to receive enough lustre to make its mercerization practical for this purpose. The gassing of the yarn before it is mercerized also seems to add materially to the lustre of the finished product. Gassing consists in rapidly passing the yarn through a gas flame for the purpose of singeing the projecting superficial fibres.

At least two other applications of mercerization have proved of importance.

First, the production of seersucker effects by printing on a cotton cloth a narrow stripe of strong caustic soda paste. The cloth shrinks where the caustic soda comes in contact, and when washed and finished, a seersucker effect results.

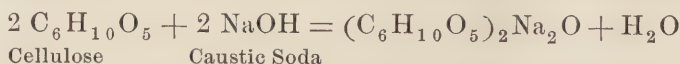
Second, the production of two-color designs by printing a figure on cotton cloth with a caustic soda paste, and then dyeing in a bath containing a direct cotton color. If the color be a blue, the result will be a light blue ground and a darker blue figure, and similarly with other colors.

This effect is due to the increased affinity for dyestuffs of that portion of the cotton fabric that has been acted upon by caustic soda.

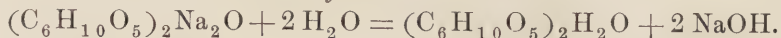
Other reagents, such as strong sulphuric acid and a concentrated solution of zinc chloride, if properly used, produce an effect similar to caustic soda, but they have never been introduced on a practical scale.

As to the chemistry of mercerization, the accepted theory at the present time is similar to that proposed by Mercer, that is, that the change is due to the formation of a hydrate of cellulose. When cotton is mercerized, a reaction represented by the following equation probably takes place:





and when mercerized cotton is washed the sodium compound is converted into a cellulose hydrate:



The chemistry of the subject has not been studied as thoroughly as the physical side, and the above is merely the accepted theory of the present time.

**29. Lime.** Milk of lime even at a boiling temperature has little or no action on cotton material as long as it remains below the surface of the liquor, but if it comes in contact with the air, at a boiling temperature, tendering takes place, through the oxidation of the fibre. Such exposure must be avoided in cotton bleaching.

**30. Chlorine and Hypochlorites.** Cotton is quickly tendered if exposed to gaseous chlorine, especially in the sunlight.

The action of bleaching powder or calcium hypochlorite on cotton varies between the following limits according to its concentration and temperature. A cold dilute solution has scarcely any action, but a hot concentrated solution will tender the fibre seriously. Hypochlorite solutions, if too concentrated or too warm, convert cellulose into oxy-cellulose. For this reason particles of bleaching powder must not remain in contact with cotton cloth any length of time, for the cloth will become so tendered in the immediate neighborhood as to cause holes. Very dilute and cold solutions of bleaching powder or hypochlorites are universally used for bleaching cotton material.

**31. Oxy-cellulose.** The tendency of all oxidizing agents is to convert cellulose into oxy-cellulose, a substance containing a higher percentage of oxygen than ordinary cellulose. Oxy-cellulose has a decided affinity for the basic dyestuffs, while cotton does not. Use is made of this fact in detecting its presence.

**32. Metallic Salts.** Cotton fibre has little or no affinity for ordinary neutral salts, such as alum, copper sulphate and ferrous sulphate, but when they are present in a basic condition it has the power of decomposing them; the metallic oxides or hydroxides formed during decomposition becoming loosely fixed upon the surface and in the pores of the fibre. In this condition the

cotton has a greater affinity for certain coloring matters. This will be considered more fully under Mordants.

**33. Action of Cotton with Coloring Matters.** Until within the last twenty years the only dyestuffs of importance for which cotton showed a direct affinity were indigo and turmeric. All others had to be applied through the use of an intermediate product called a *mordant*.

Some of the basic dyestuffs may be said to have had a slight affinity, but with the discovery of Congo red, in 1884, a new class of artificial dyestuffs known as the direct cotton colors came into use, and these at the present time are capable of producing on cotton, without the use of a mordant, almost any shade except very bright blues and very bright greens.

#### FLAX AND LINEN.

**34.** Next to cotton, linen is the most important vegetable fibre. It is the product of the flax plant, the variety commonly cultivated being known botanically as *Linum Usitatissimus*.

Flax grows best in a temperate climate, and is cultivated in nearly all parts of Europe, and to a considerable extent in the United States. It is an herbaceous plant, with long, narrow, smooth leaves, and bearing bright blue flowers, which ripen into the seed valuable for the production of linseed oil.

In order to produce a product satisfactory for textile purposes, great care is necessary. The production of good linseed and valuable fibre from the same plant, is said often to be impossible, but facts established in other countries as well as in our own, indicate otherwise. In Belgium, for instance, the finest linen of Europe is grown, and the seed from the same plant is not only saved, but a portion used for the production of the next year's crop. It is a fact, however, that if the flax is allowed to grow beyond a certain point, the fibre becomes stiff and coarse; and the double result can be obtained only when the flax-grower has had experience, and the conditions are favorable. Many flax-growers of the United States sacrifice the value of their crops, as far as the fibre is concerned, for the purpose of producing large quantities of rich seed.

**35. Removal of the Seed.** The process known as rippling

has for its object the removal of the seeds, and is accomplished by drawing the flax stalks through a series of iron combs. In this country the seeds are often removed by passing the flax through threshing machines, but this renders the flax worthless so far as the production of the fibre is concerned.

The seeds, if ripe enough, are used in the preparation of linseed oil, the most valuable of the common drying oils.

**36. Retting.** Whereas cotton is ready for the textile manufacturer immediately after it has been ginned, flax has to undergo a series of operations, involving both mechanical and chemical principles, before workable linen fibre can be obtained. This is necessary because after rippling, the air-dried flax contains less than 30 per cent of actual linen fibre, the remainder being wood, pith and rind, which cling to the fibre with great tenacity. The process of separating the fibre is thus rendered difficult. It involves several operations, and is commonly called retting.

Retting is carried out in a number of different ways, but in every case the object is to decompose by fermentation and otherwise, the pulpy and resinous matter that holds together the woody material and actual fibre, and thus render the two separable.

The different methods of retting may be classified as follows:

Natural retting.

- (1) By steeping in stagnant water.
- (2) By steeping in running water.
- (3) Dew retting.

Artificial retting.

- (1) Retting with warm water.
- (2) Retting with steam under pressure.
- (3) Retting by the use of mineral acids.

*Retting in stagnant water* is carried out mainly in Russia and Ireland. The flax is steeped in pools or tanks of soft water. In the course of a few days fermentation sets in and the resinous and pulpy matter becomes more or less soluble, thus facilitating the separation of the fibre from the woody material. The retting is completed by exposing the flax in the fields to the action of the sun and atmosphere for a few days.

*Retting in running water* is accomplished by packing the flax in crates, and immersing these crates in streams of water, so that there is a slow but constant flow of water through them.



Fermentation soon begins, and the retting is completed in from ten to twenty days. The flax is sometimes removed during the process, exposed to the sun for several days, and returned to the water. This form of retting is used chiefly in France and Belgium, and gives a lighter colored linen than the previous method.

*Dew retting* is accomplished by exposing the flax in a moist condition to the action of the dew and sun, by keeping it spread in a field during a period of ten weeks. This takes longer than either of the previous methods, but produces a whiter linen. This form of retting is used largely in Germany and Russia.

The artificial methods of retting are of less importance than the natural, since they are at present in a more or less experimental stage. The object of all artificial methods is to shorten the extended period of time, and reduce the territory needed to carry out the natural, and in some cases to prevent the obnoxious odor arising from the fermentation.

*Warm Water Retting.* This is accomplished by steeping the flax in warm water at  $30^{\circ}$  to  $35^{\circ}$  C. for two or three days, when the resinous material becomes so softened as to readily squeeze out when the stalks are passed between squeeze rollers.

*Retting with Hot Water and Steam.* This is the quickest of all retting processes. The flax is first exposed in strong iron cylinders to the action of water at  $150^{\circ}$  C., under pressure, for 30 to 40 minutes, and then to the action of high pressure steam at the same temperature for 30 minutes. Under these conditions the resinous material of the flax becomes soluble and is removed during a subsequent washing. The whole process takes but a fraction of a day.

*Retting with Mineral Acids.* Under this head might be included a number of methods by which small quantities of different acids, such as sulphuric and hydrochloric, are added to the retting bath. The addition of acid not only lessens the time as compared with the natural fermentation method, but prevents the disagreeable smell.

**37. Breaking.** After retting, the flax is subjected to several mechanical operations, the object of which is to remove the woody portions of the stem as completely as possible. The first of these



PRESSURE-HYDRO-EXTRACTOR FOR EXTRACTING  
WATER FROM CLOTH

Rodney Hunt Machine Co.





operations is known as breaking, and its object is to break up the woody portion of the stalks, so that it may be removed from the fibre.

This was formerly done by hand with indented wooden mallets, but at present is generally accomplished by passing the stalks through a series of fluted rolls.

**38. Scutching** is the next operation, and consists in the removal of the broken particles of wood either by hand or machinery, thus leaving the fibre in a more or less free condition.

**39. Hackling or Heckling.** The last of the series of mechanical operations is known as hackling or heckling. It has for its object the separation of the fibres into an individual state and laying them parallel to each other. This is accomplished by drawing the flax through several combs; the first are coarse, and then finer and finer, until it is in a suitable condition for being spun.

Two products are the result of this operation :

First: Flax line, which consists of the long, straight and more valuable fibres; and

Second: The tow, which includes the short and more or less tangled fibres.

**40. Linen Fibre.** Flax line commonly has the appearance of a long, fine, soft and lustrous fibre, varying in color from a yellowish buff to a greenish gray. When examined under the microscope, what appeared to the naked eye to be a single fibre will often prove to be composed of a number of smaller fibres cemented together. If these are separated, the ultimate single fibre appears as a long transparent tube, often striated longitudinally, possessing thick walls and a minute central canal. At irregular intervals faint transverse markings may be detected, and these are often pronounced in the larger fibres. (See Fig. 6.) Flax line varies considerably in length and diameter, since it is composed of a varying number of constituent fibres, but the ultimate fibres are approximately 25 to 30 millimeters in length, and .02 to .025 millimeters in diameter.

Linen is stronger than cotton, possesses greater lustre, and is a better conductor of heat. It is for the latter reason that it makes cooler clothing. Linen is hygroscopic to about the same extent as cotton, containing 6 to 8 per cent of moisture.

**41. Chemical Composition.** Like cotton, linen consists for

the most part of cellulose, but in the raw and unbleached state it is mixed with from 15 to 30 per cent of natural impurities. Among these natural impurities, pectic acid is the most abundant, and this is accompanied with smaller amounts of fatty and coloring matters.

**42. Action of Reagents.** In general, linen acts like cotton with reagents. Schweitzer's Reagent dissolves pure linen as readily as it does cotton.



Fig. 6.

The action of mineral acids on bleached linen is almost identical with their action on cotton, but in the case of raw and unbleached linen the action is a little more energetic, owing to the large percentage of natural impurities present. For this reason, linen is also rendered

much more difficult to bleach than cotton.

The action of mordants and dyestuffs on linen is very similar to their action on cotton, but linen is usually more difficult to dye, not being as easily penetrated as cotton.

#### JUTE.

**43.** Jute is the most important vegetable fibre after linen. Its principal source is India. The processes of its treatment are very similar to those of linen, but it differs from both cotton and linen in its composition. It contains no cellulose in the free state, but instead is composed chiefly of a combination of cellulose and bastose, the latter being a compound intermediate between the carbohydrate and aromatic compounds, and possessing to some extent the properties of both.

*Bastose* is much more easily acted upon by chemical reagents than cellulose, and for this reason the action of various chemical reagents on jute is entirely different from their action on linen and cotton, jute being much more sensitive to the action of acids and not standing as much treatment, even with water. When treated

with hypochlorites, the liberated chlorine forms a chlorinated compound, and when treated with alkalis, bastose is decomposed into cellulose and an insoluble tannin product.

For these reasons, jute cannot be easily bleached in the same way as cotton and linen, and in fact is seldom bleached.

**44. Action of Dyestuffs.** Jute may be said to be a naturally mordanted fibre, since it contains a certain amount of tannin material, which acts as a mordant for certain dyestuffs. This is the reason why it takes up many basic dyestuffs directly. Jute may be dyed with the direct cotton colors, but it is largely used in making bagging, burlap, backs of carpets and in upholstery, where there is no necessity for dyeing.

#### HEMP.

**45.** Hemp resembles flax in nearly every way, and its treatment is similar. It is, however, much coarser than linen, and is seldom bleached or dyed.

It is used chiefly in making rope, twine and bagging.

#### RAMIE.

**46.** Ramie fibre or China grass is the fibre obtained from a form of nettle grown in China, India, and in an experimental way in the United States. In the best samples of ramie the individual fibres are 20 centimeters long, with a diameter varying from .04 to .08 millimeter. When purified and cleansed, ramie possesses a characteristic and silk-like lustre which surpasses that of linen.

In composition it consists mainly of cellulose, accompanied in the unbleached state with about the same percentage of natural impurities as cotton.

Although easily bleached, some difficulty is experienced in dyeing full and bright shades without injuring its lustre.

The great drawback to its extensive use and cultivation is the difficulty experienced in separating by mechanical means the individual fibres from the stem and bark in a condition satisfactory for spinning. Several processes have been devised for retting and separating the fibre, but as yet, neither the European nor the American product can compete either in price or quality with the



ramie imported from China, the latter being separated entirely by hand, where labor is valued at only a few cents per day.

The Chinese are also far ahead of all other nations in the spinning and weaving of ramie, but experiments along this line performed of late in this country have proved very encouraging.

**47. The other vegetable fibres** of importance are Manila hemp, sunn hemp, New Zealand flax, and the products of the leaves of different palms, and the fibrous material that surrounds the cocoanut. These fibres, however, are seldom dyed, and will not be further discussed.

#### WOOL.

**48.** The most important animal fibre is wool. This term is applied to the hairy covering of a number of animals. In the strictest sense it is the hairy covering of sheep, but for practical reasons the hair of certain goats, as the cashmere, mohair and alpaca, and of camels is generally classified under the same head.



Fig 7.

strength, elasticity, color, etc. Different portions of the same animal also give a varying quality of fibre; that from the shoulders and upper portion being finer than that from the lower.

It is necessary that these different qualities be separated by hand, and the process is known as *wool sorting*.

According to the average length of fibre, wool is divided into two general classes: long and short staple. The former is commonly carded, combed and spun into worsted yarn, while the latter is generally carded and spun into woolen yarn.

**49. Diseased Wool and Its Action toward Dyestuffs.** The wool of diseased sheep, especially if taken from the hide after death, is of a very inferior quality, and experiments show that its action toward dyestuffs is different from that of perfectly healthy wool; the diseased wool when dyed lacking the brilliancy characteristic of the normal wool.

**50. Wool Fibre.** Wool has a characteristic physical structure which distinguishes it from other fibres. Undoubtedly no one has made a more thorough study of the physical structure of wool fibre than Dr. F. H. Bowman, and according to his authority wool is a product of the epidermal layer of the skin and is built



Fig. 8

up of innumerable individual cells; when examined carefully under the microscope it will be found to consist always of two and sometimes of three portions.

These three portions are:

- (1) External or horny covering.
- (2) Cortical or underlying body of fibre.
- (3) Medullary or central portion.

Under the microscope wool fibre appears as a solid rod-shaped substance, the surface of which is covered with broad horny plates, all projecting in the same direction, and much resembling the scales of a serpent or fish, as shown in Figs. 8 and 9.

The cortical comprises the body of the wool and sometimes the entire portion of the fibre underlying the outer horny covering. It is built of a large number of spindle-shaped cells of a more or less horny character.

The medullary or central portion of the wool (see Fig. 10) appears to be wholly lacking in the finest grades of wool. When noticeable, it seems to be composed of larger cells than the sur-

rounding cortical, which are more or less rhombic, or cubical, and of a marrowy nature. Under the microscope, this portion of the fibre appears darker than the rest, but may be rendered nearly transparent by boiling with glycerine or turpentine.

Wool is a very elastic fibre; much more so than any of the vegetable fibres. The average length of wool varies with the different grades from  $1\frac{1}{2}$  to 20 inches, and the diameter from .004 to .0018 inch.

**51. Hygroscopic Moisture.** Wool fibre is much more hygroscopic than any of the vegetable fibres. The amount present may



Fig. 9.

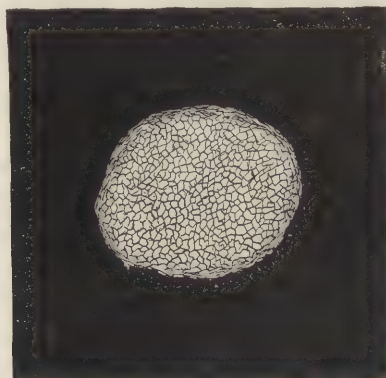


Fig. 10.

vary from less than 10 per cent to more than 30 per cent, depending mainly upon the conditions of the atmosphere where the wool has been stored.

The process of determining the quantity of moisture present is known as *conditioning*, and will be considered more fully under Silk. The wool-conditioning establishments of Europe take 18.25\* per cent moisture as the standard, while the percentage accepted in this country may be a trifle lower.

**52. Felting.** The characteristic superficial structure of wool plays an important part in its felting properties.

When a large number of wool fibres are pressed together, especially in the presence of hot water, soap and an alkali, which soften the external horny scales, the opposing scales gradually

\*NOTE. For worsted tops. Raw unscoured wool may be as low as 10%.



work themselves together, and when the wool has become cooled and dried the softened scales harden, the fibres set are tightly held together, and the wool is said to be felted. This principle is of valuable application in the finishing of certain classes of wool goods.

**53. Affinity of Cortical for Dyestuffs.** The cortical appears to have a greater attraction for dyestuffs than the exterior scaly covering. This may account for the fact that an acid bath is sometimes advantageous in certain wool mordanting and dyeing processes, the acid having a tendency to open the exterior scales and cells, thus exposing the interior. This also explains why carbonized wool may be dyed deeper shades and more rapidly than ordinary wool.

**54. Kemps.** Here and there in wool are sometimes seen fibres that appear almost like ivory. If examined under the microscope, they will be found to be void of any of the characteristic structure of wool. These fibres come from portions of the sheep where the wool has merged into hair. They cannot be felted, are difficult to dye, and often appear in the dyed goods as light specks. They are technically known as kemps.

**55. Composition of Wool Fibre.** A careful chemical examination of raw wool will show that the foreign matter present is often far in excess of the actual wool fibre. When properly cleansed and freed from all accompanying substances, the fibre is found to possess a chemical composition similar to that of horn and feathers, and consists of what is termed *keratin* (horny substance).

The elementary composition varies somewhat in different qualities of wool, but the following may be taken as representative:

Carbon	49.25 per cent.
Hydrogen	7.50 per cent.
Oxygen	23.75 per cent.
Nitrogen	15.75 per cent.
Sulphur	3.75 per cent.

**56. Foreign Matter in Raw Wool.** The foreign matter enveloping the actual wool fibre possesses a special interest to the dyer, for on its entire removal depends, to a great degree, the success with which pure, even and fast colors may be obtained. To the manufacturer and merchant it is also of great importance,

since the amount present in raw wool varies considerably and effects its commercial value.

**57. Wool Suint or Perspiration.** By extracting raw wool with warm water until all matter soluble in this reagent is removed, and then evaporating the extract to dryness, a residue is obtained which consists essentially of the potassium salts or soaps of certain fatty acids, particularly oleic, stearic, palmitic and acetic acid, together with the potassium salts of some mineral acids, such as hydrochloric and phosphoric. Small quantities of certain ammonium compounds are also present. This extract is known as wool suint or perspiration and is essentially that portion of the impurities soluble in water.

**58. Wool Yolk.** If, after all the water-soluble matter has been removed, the wool is extracted with alcohol and ether, and the extract evaporated to dryness, the residue will be found to consist of a mixture of various fatty compounds. For the most part they are not glycerides, but compounds of the alcohols chloresterin and isochloresterin with certain fatty acids, and this accounts for the difficulty sometimes experienced in their removal by mild scouring agents.

**59. Mechanical Impurities and Dirt.** When all the extractive matter has been removed, there remains a varying amount of insoluble mineral and organic matter, which was held mechanically to the wool through the adhesive nature of the yolk.

**60. Composition of Raw Wool.** Taking an average of the results of various investigators on different grades of raw wool, the following may be given as fair limits:

Moisture	4 to 30 per cent.
Combined Yolk and Suint	12 to 47 per cent.
Actual Wool Fibre	15 to 72 per cent.
Mechanical Impurities and Dirt	3 to 24 per cent.

As a rule the best grades of wool contain the highest percentage of combined yolk and suint.

Some authorities include suint under the head of yolk, but this does not draw a sharp dividing line between that portion of the impurities soluble in water and the portion that is insoluble.

**61. Influence of Sulphur.** The amount of sulphur in wool varies considerably, and whether or not it is an essential constit-

uent of wool has been much discussed. It seems, however, to occur in all wool in some form or other, and its presence may be considered an advantage in some respects and a disadvantage in others.

Certain dyestuffs, particularly naphthol green and malachite green, have a greater affinity for wool that has been mordanted with sulphur, and when dyeing with these and similar colors its presence would naturally be an advantage. On the other hand, wool containing much sulphur is likely to become spotted if it comes in contact with certain metals or their salts, especially lead and copper.

#### ACTION OF DIFFERENT REAGENTS ON WOOL.

**62. Heat.** If wool is heated to  $100^{\circ}\text{C}$ . in a moist atmosphere, it becomes plastic, may be worked or bent in any shape, and when cooled this shape is retained. This is of great advantage in wool finishing.

If heated above  $100^{\circ}\text{C}$ . in a dry atmosphere, wool loses all its hygroscopic moisture and becomes harsh, but when exposed to ordinary atmosphere it takes up moisture and resumes its natural feel. At a temperature of  $130^{\circ}\text{C}$ . it commences to decompose, giving up ammonia and water vapor, and at  $145^{\circ}\text{C}$ . it gives up sulphur vapor. In a direct flame it burns with difficulty, emitting the disagreeable odor characteristic of burning feathers.

**63. Acids.** Dilute mineral acids, such as sulphuric, hydrochloric and nitric, may be said to have no appreciable effect upon wool fibre, although they are absorbed and retained with great tenacity and are not readily extracted even with boiling water.

Nitric acid, if sufficiently concentrated, gives a yellow color to wool. The color produced by certain dyestuffs may be stripped from wool by boiling with dilute nitric acid. Care should be taken that the acid is not too strong, and the boiling should not last over three or four minutes.

In the case of concentrated acids, the fibre soon begins to disintegrate, but in no case is the action so destructive as on cotton fibre. Dilute acids may be dried upon the fibre even at high temperatures without any noticeable tendering, and this fact is made use of in carbonizing.

**64.** Sulphurous acid,  $\text{H}_2\text{SO}_3$ , or sulphur dioxide,  $\text{SO}_2$ , has



the power of removing the natural yellow color of ordinary wool, and is the commonest, and all things considered, probably the best bleaching agent employed for this fibre.

Wool treated in this way is very persistent in retaining the sulphur dioxide, and this should always be removed previous to dyeing, especially in the case of light colors. This may be effected by steeping the wool in a very dilute solution of sodium carbonate or bleaching powder. When the first reagent is used, the acid is merely neutralized, but in the second case the sulphurous acid is oxidized to sulphuric acid.

Should the removal of the sulphur dioxide be neglected, the dyed wool is likely to be decolorized by the bleaching action of the portion remaining in the fibre.

**65. Alkalies.** Alkaline solutions in general have a noticeable action on wool, but the effects produced vary considerably according to their nature, concentration, temperature and period of the action. Caustic alkalies—sodium hydroxide and potassium hydroxide—act injuriously on wool fibre under nearly all circumstances. Even when applied in cold and dilute solutions they act injuriously, and for this reason they cannot be used as scouring agents.

It should be noted, however, that cloth composed of cotton and wool is sometimes passed through a concentrated solution of caustic soda to produce a mercerizing action on the cotton. In this case the caustic solution is cooled with ice, and the cloth passes directly through the bath into an excess of water.

It should also be noted that experiments with solutions of the caustic alkalies of different concentration show that a very strong solution has far less action upon wool fibre than one moderately dilute.

Hot solutions of caustic alkalies, even when dilute, dissolve wool to a soapy liquid, from which a white amorphous mass is precipitated by the addition of acids.

Solutions of the alkaline carbonates and of soap have little or no injurious action if they are not too concentrated and the temperature is not higher than 50° C.

Soap and carbonate of ammonia have the least injurious effect, while the carbonates of potassium and sodium tend to give the

wool a yellowish color and render it slightly harsh and less elastic.

The different action of the various alkalies under different conditions is of the utmost importance in wool scouring, and will be considered more fully under that head.

**66. Chlorine and Hypochlorites.** The action of chlorine and hypochlorites on wool is ordinarily harmful, although used to advantage in the production of chlorinated wool.

A hot solution of bleaching powder will entirely destroy the fibre, liberating nitrogen. Dilute solution, when cool, will turn wool yellow. For this reason hypochlorite solutions, so extensively used in the bleaching of vegetable fibres, cannot be used in wool bleaching. Even the very dilute solution sometimes used to destroy the sulphur dioxide in bleaching is deleterious to a certain extent.

#### CHLORINATED WOOL.

Wool readily absorbs chlorine gas, and under certain conditions may take up 30 per cent of its own weight. If the chlorine is dry and the wool not too moist, this absorption of chlorine seems to impart a decided lustre and the scroopy feel of silk to the fibre without seriously tendering it. Wool treated in this way is known as chlorinated wool, and is produced commercially. Chlorinated wool also has an increased affinity for dye-stuffs, and this fact is used in the production of two-color effects in a single dye bath. This increased affinity for colors is probably due to a partial oxidation of the fibre.

Chlorinated wool may also be produced by the following, which is recommended by W. J. Matheson & Co.

For 100 pounds of wool either in the loose state or form of yarn, treat as follows:

First enter the material for a half hour in a cold bath containing  $1\frac{1}{2}$  pounds concentrated hydrochloric acid per 10 gallons of water. Then squeeze gently and work in a bath made up as follows:

For Hard Wools.

15 to 20 pounds of Bleaching Powder.  
350 gallons of water.

For Soft Wools.

20 to 25 pounds of Bleaching Powder.  
475 gallons of water.

In either case the Bleaching Powder solution when made up should have a strength of between .6° and 1° Tw.

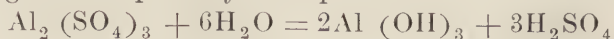
After working in the above bath for a half hour, add to the same bath 3 ounces hydrochloric acid per 10 gallons of bath and work for another ten minutes.

Then re-enter the first acid bath, to which has been added 8 ounces of hydrochloric acid per 10 gallons of bath, work fifteen minutes, and wash thoroughly in cold water. If after the final washing a decided smell of chlorine is still perceptible, it is advisable to treat the material for another fifteen minutes in a bath containing 5 per cent (weight of wool) of sodium thiosulphate at 86° F. and then rinse again.

The chlorinated wool is then ready for use, and if woven with ordinary scoured yarn, will produce a plain cloth which will give a two-color effect when dyed.

**67. Metallic Salts.** There seems to be no chemical action between wool and solutions of salts which are neutral in reaction, such as sodium chloride, sodium sulphate and calcium chloride, but when boiled for some time with such metallic salts as aluminium sulphate, ferrous sulphate, chromium sulphate, chrome alum, etc., which are slightly acid in reaction, there is more or less absorption of these metallic compounds by the wool. The fibre apparently decomposes the salts during the boiling in such a manner that a basic salt, oxide, or hydroxide of the metal is precipitated in the pores of the fibre, and free acid remains in solution.

Taking the case of aluminium sulphate as an example, the following reaction probably takes place:



the aluminium hydroxide being absorbed by the fibre, and the sulphuric acid remaining in solution.

The basic compounds deposited in this way seem to have a great attraction for certain coloring matters, forming with them permanent lakes. Upon these facts depend most cases of wool mordanting. This method of mordanting is not applicable to the vegetable fibres, since they do not possess the power of decomposing salts in this way.

**68. Coloring Matters.** Wool may be said to exert the



greatest affinity for coloring matters of any of the textile fibres. It combines directly with all the substantive colors, and has a tendency to combine with a number of the adjective colors, if the bath is in the proper state of neutrality or acidity. Being somewhat porous, wool is readily penetrated by solutions, especially when heated, and this contributes to the easy manner in which it takes up coloring matters.

**69. Quantitative Separation of Wool from Cotton.** At this point it might be well to emphasize the marked difference between the action of acids and alkalies toward cotton and wool. Acids completely destroy cotton, with little, if any, destructive action on wool, while alkalies will destroy wool, and have no destructive action toward cotton.

Upon these facts are based two methods for determining quantitatively the amount of cotton and wool present in a piece of union material.

(1) If the cloth is saturated with dilute sulphuric acid, and dried, without washing, at a temperature of  $100^{\circ}\text{C.}$ , and then briskly rubbed between the hands, the cotton, which has become carbonized, will fall out as a grayish-white powder. If the material is weighed before and after this treatment, the loss of weight will be the amount of vegetable fibre present. This method, however, can be used with only certain classes of goods, and is not as accurate or satisfactory as the following:

(2) Weigh carefully a small piece of material, and boil it for four or five minutes in a 4 per cent solution of caustic soda.

At the end of this period the wool will be completely dissolved by the caustic soda, and if the weight of the dried residual textile material is subtracted from the original weight of the cloth, the loss will represent the percentage of wool or similar fibre present.

#### SILK.

**70.** Among the animal fibres, silk is next in importance to wool. Silk is the light yellow, white or buff-colored fibre that the silkworm spins and uses as a covering when it passes from the *caterpillar* into the pupa or chrysalis state. It differs from the vegetable fibres as well as from wool in that all cellular structure is absent.

**71. Varieties and Sources.** Silk may be divided into two classes, wild and cultivated.

Wild silk is the product of certain wild moths which are natives of India, China and Japan. It is of minor importance as compared with the cultivated.

Cultivated or artificially reared silk is the product of the common silk moth (*Bombyxmori*), which has been studied and cultivated for a period of several thousand years. The important sources of cultivated silk are southern Europe, particularly France and Italy, Turkey, China, India and Japan.

**72. Rearing Silkworms.**

Eggs of the common silk moth are of a yellowish to gray color, and about the size of poppy seeds; about 40,000 weigh an ounce. In Eastern countries, China and Japan, the eggs are hatched and the worms raised in the open air, but in Europe, specially constructed buildings called *magnaneries* are used for these purposes.



Fig. 11.

The eggs are laid out on sheets of white paper in these buildings, which are well lighted and ventilated. The atmosphere is kept at a constant degree of moisture, and the temperature is gradually raised from 18° C. to 25° C. during the period of from ten days to two weeks. At the end of this period the perfect eggs hatch, and the worms are transferred to a large, airy room, and fed at regular intervals on the leaves of the mulberry-tree for a period of from four to four and a half weeks, when they stop eating and are ready to spin.

At this time the worms, which have now grown to consider-

able size, weighing as much as five grams, are transferred to another room containing loose twigs, and upon these the silkworms immediately attach themselves and begin to spin. (See Fig. 11.)

**73. *The Cocoon.*** When the spinning operation begins, the silkworm builds about itself the cocoon, in which it lives during the chrysalis state. While spinning, the silk issues from the spinneret of the silkworm at the rate of from four to six inches per minute; the worm making during that time about sixty-five elliptical movements of the head, or a total of 300,000 in the average cocoon. The time taken by the worm in spinning the cocoon is three to five days.

The silk substance is secreted by a pair of glands, which are symmetrically located along the sides of the body. Each gland consists of three parts, as shown in Fig. 12: a small tube, which extends into the body; an enlarged continuation of this tube, C B, which comprises the main portion of the gland, and a contracted continuation, B A. The portion B A of both glands meet at the spinneret S, thus giving rise to the double structural formation of silk, which will be described later.

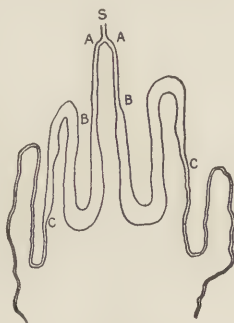


Fig. 12.

While the worm is spinning, the central portion of the large gland, C B, contains a clear, colorless, gelatinous liquid, which appears to merge into a slightly different liquid toward the walls of gland. When the silk substance arrives at A it solidifies and issues from the spinneret S as a double fibre. The central substance of the gland forms the actual fibre, while the outer liquid furnishes the silk gum that cements the two fibres together. It is this latter portion that is removed during the silk boiling, or degumming, as it is often called.

The cocoons are thus made of a continuous double fibre rarely broken, and from 1,200 to 4,000 feet, or even more, in length. They are generally of a white to yellowish color, and about three centimeters in length, and 1.5 to 2 centimeters in thickness.

**74. *Treatment of the cocoons.*** When the change from the



caterpillar to the chrysalis state is complete, the cocoons are collected. A few are selected for breeding purposes and placed in a room kept at a temperature of about  $20^{\circ}\text{C}$ . At the end of three weeks the silk moth has been formed in the cocoon, and by emitting a peculiar saliva, which softens and separates the fibre of the cocoon, it forces its way out. In a few days the female moths lay their eggs. These are collected, slowly dried, and stored in glass bottles in dry, dark rooms until the following spring.

The cocoons which are to be used for the production of silk are either subjected to steam or heated to  $60^{\circ}$  to  $70^{\circ}\text{C}$ . to kill the pupæ contained within. This takes from ten to fifteen minutes.

When killed by steam, the cocoons are allowed to remain in the damp state for a short time, but after a few hours are placed in a dry room and moved about until they become dry.

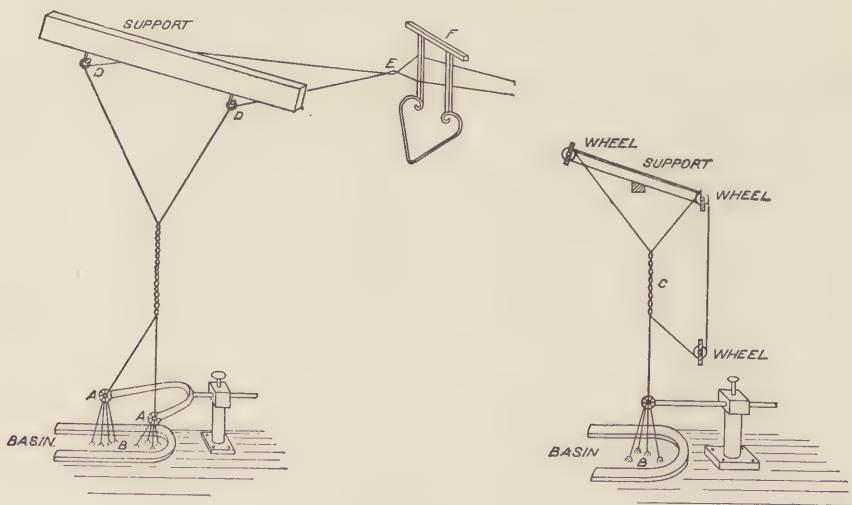
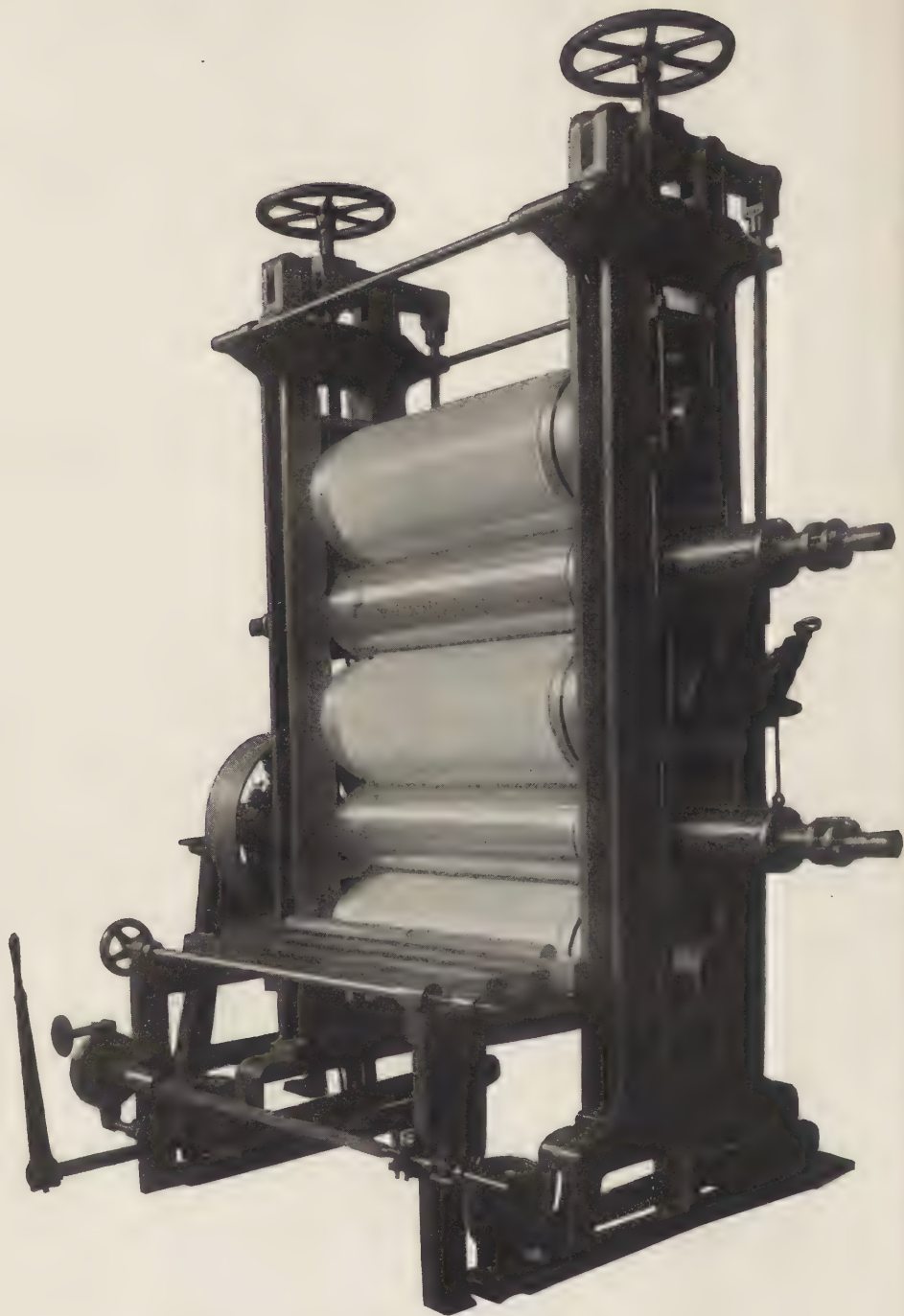


Fig. 13.

**75. Raw Silk.** The next step in the process of silk making is called reeling. The cocoons are sorted into grades of different quality. The best cocoons are selected for the preparation of warp thread, commonly called organzine, as that has to be strong, lustrous and tightly twisted. The poorer cocoons are commonly worked up for weft or filling, which contains fewer individual fibres, less twist than the organzine and is commonly known as tram.





FIVE-ROLL CALENDER FOR COTTON AND LINEN GOODS

Textile Finishing Machinery Co.



In the reeling operation a number of cocoons are placed in a basin of warm, soapy water, and a skilled operative is able by the aid of a little brush or broom, often made of briar twigs, to catch the outer end of the fibre. When this has been done with the proper number, which may vary from three to as many as twenty, the ends are placed together, passed through a smooth guide, sometimes made of agate, and then twisted several times about a thread of similar structure to give it twist and make it smooth. This twisted thread then passes through another guide and on to a large reel. The accompanying cuts (Fig. 13) will give an idea of the process.

Silk reeled directly from the cocoon is of the most valuable quality, and constitutes the raw or net silk of commerce.

The tangled and fine loose ends of the cocoon, as well as that obtained by degumming the broken and injured cocoons, are combed

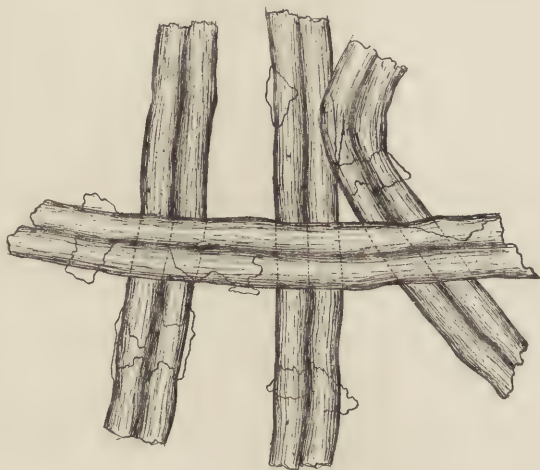


Fig. 14.

like flax and spun similar to worsted into what is known as spun or floss silk.

**76. Silk Fibre.** Silk is characterized by its lustre, strength, elasticity and remarkable avidity for moisture. Another characteristic property of silk is the peculiar crisp, crunching sound, or rustling, produced when it is handled, known as the *seroop* of silk. It is a poor conductor of heat and electricity, but is easily electrified. This latter fact is one of the drawbacks in silk manufacturing, but can be overcome to a certain extent by keeping the air at the proper degree of moisture. Silk can be stretched  $\frac{1}{7}$  to  $\frac{1}{6}$  its length without breaking.

A microscopical examination of raw silk shows it to be a double fibre. Occasionally the double fibre separates for a short distance into its components, and at these places the appearance is that of two solid cylindrical fibres. These two fibres are gummed or glued together by what is termed silk glue, or sericin.

**77. Hygroscopicity.** As already mentioned, silk-like wool is very hygroscopic, absorbing more than 30 per cent of moisture without feeling the least moist.

Owing to the high price of silk it is necessary that the seller as well as the buyer should know the percentage of actual silk they are handling. This fact has resulted in the establishment throughout the silk districts of what are known as "conditioning establishments." At these establishments the amount of moisture in excess of 10 per cent, which is considered normal, is determined. The commonest form of apparatus for this purpose is the Talabot Persoz Rogeat, shown in Fig. 15. In this apparatus the silk is kept constantly at 221° F. until constant weight is attained, it being possible to determine the weight of the silk at any time without its removal from the apparatus.

**78. Composition.** Chemically, raw silk may be said to be composed of two entirely different substances.

First:—An outward envelopment of gummy material, which is quite readily soluble in such reagents as water, alcohol and ethers.

Second:—An inner portion, the true fibre, which withstands the action of all ordinary reagents.

The first to make an extensive study of the composition of silk was Mulder, and he assigned the name of fibroin to the inner insoluble portion, and to the outer gummy portion the name sericin has been given.

The fibroin constitutes about 65 per cent of raw silk. It is insoluble in water, but soluble in strong acids, alkalies and Schweitzer's reagent.

Sericin, or silk glue, is a gelatinous substance, soluble in water, from which it can be precipitated by lead acetate. Investigations lead to the conclusion that sericin is a product of fibroin through oxidation and hydrolysis.

For all practical purposes we may consider the fibroin as the actual silk fibre, and the sericin the silk glue or gum which envelops it and holds the two constituent fibres of the raw silk

together. It is the sericin that is removed during the silk boiling or degumming process.

Commercial, or boiled-off, silk usually gives .7 to 1 per cent of ash, consisting mainly of the oxides of calcium, magnesium, aluminum and iron.

#### ACTION OF DIFFERENT REAGENTS.

**79. Water.** Water, either cold or boiling, has no action on silk other than to remove the sericin from raw silk.

**80. Acids.** In general, silk is readily attacked and dissolved by concentrated mineral acids, while dilute mineral acids and solutions of the organic acids are much milder in their action.

Concentrated hydrochloric acid will dissolve more than its own weight of silk. Upon addition of water to this solution the silk separates as a flocculent precipitate. If applied in the gaseous state, hydrochloric acid will rapidly disintegrate silk. Even when somewhat diluted, boiling hydrochloric acid has an action on silk, but when very dilute has little action other than to remove the sericin. The action of hydrochloric acid on silk is valuable in its detection.

Concentrated nitric acid rapidly destroys silk, dissolving it to a yellow solution, but dilute acid simply colors the fibre yellow. This latter reagent may be used for distinguishing silk from vegetable fibres.

Concentrated sulphuric acid dissolves silk to a brown viscous solution. Warm dilute sulphuric acid, however, simply dissolves the sericin of the raw silk and may be used in the degumming process.

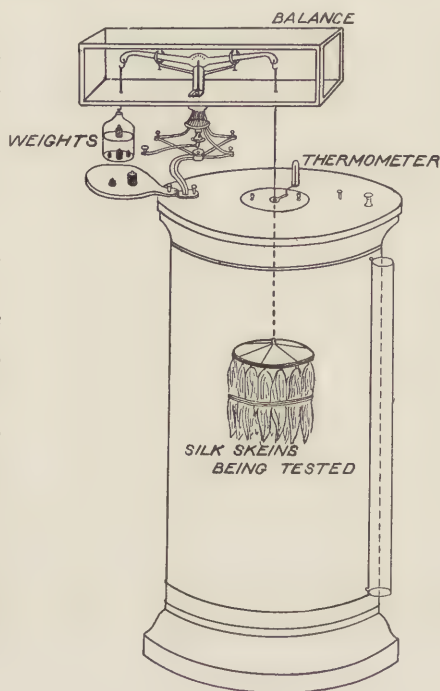


Fig. 15.



Most other acids, as phosphoric and arsenic, act as dilute mineral acids. Dilute acetic acid, even when hot, has no injurious action, and is in fact used to brighten dyed silk. Silk, however, will completely dissolve when heated under pressure with glacial acetic acid.

Sulphur dioxide, either gaseous or dissolved in water, destroys the yellow color of silk, and is consequently sometimes used to bleach it.

**81. Alkalies.** Concentrated solutions of the caustic alkalies, especially when hot, dissolve silk rapidly, but at a low temperature the action is slight. Very dilute solutions of the caustic alkalies, potassium and sodium, dissolve the sericin without attacking the fibroin, but as the tendency is to diminish the whiteness and brilliancy of the fibre, they cannot well be used in the degumming process.

The alkaline carbonates, potassium and sodium, have a similar action to caustic alkalies, but are less energetic. Ammonia has but little action. Soap and borax have no appreciable effect upon the true silk fibre, or fibroin, although they dissolve sericin. For this reason they are valuable in the silk-degumming process.

Lime renders silk brittle and impairs its lustre.

**82. Oxidizing Agents.** Chlorine or hypochlorites, if at all concentrated, will destroy silk. Very dilute solutions of these reagents give silk an increased affinity for certain coloring matters, but their action is nevertheless detrimental to the strength of the fibre.

Chromic acid destroys silk, bichromate of potash turns it yellow, and permanganate of potash gives it a brown color.

**83. Metallic Salts.** Silk behaves similar to wool in respect to its action toward such salts as those of aluminum, iron and tin. When silk is steeped in cold and not too dilute solutions of these salts, absorption takes place, which is probably due to the formation of metallic hydrates or insoluble basic salts, on or in the substance of the fibre.

The mordanting and weighting of silk depend upon this fact, but will be discussed more fully under their respective heads.

**84. Solvents of Silk Fibre.** The following may be mentioned as the best solvents of silk: Concentrated hydrochloric acid

(sèe Art. 80). Zinc chloride solution  $140^{\circ}$  Tw. will dissolve silk to a thick, sticky liquid. Schweitzer's reagent also dissolves silk.

**85. Action of Coloring Matters.** Silk, like wool, has a strong affinity for, and can be dyed directly with, most of the artificial coloring matters except the true mordant dyestuffs. Silk has but little attraction for mineral coloring matters.

**86. Wild Silks.** There comes to the market, chiefly from India, fibres produced by silk moths other than the common silk moth already described. The most important of these are the Tussah, Eria, Muga, Atlas, and Yama Mai. Of these the Tussah silk is the most common, and is used in considerable quantity in the manufacture of plushes.

Physically, wild silks differ from the mulberry silk in that the fibre is commonly longer and of greater diameter, and each individual fibre is composed of a large number of fibres, which gives it a striated appearance when viewed under the microscope. It is also darker in color than the mulberry silk.

In general, Tussah silk is not as readily acted upon by reagents as the mulberry silk.

#### SPECIFIC GRAVITY OF LIQUIDS.

The specific gravity (commonly written Sp. G.) of any liquid is the ratio between the weight of a certain volume of that liquid and the weight of an equal volume of water at the same temperature.

Water at  $4^{\circ}$  C or  $39.2^{\circ}$  F is usually taken as the standard, this being one of the constants of water, namely, the temperature at which it is at its maximum density and minimum volume; but this is not strictly adhered to, for it is often convenient to use a temperature more easily obtained, namely,  $15.5^{\circ}$  C or  $60^{\circ}$  F.

As commonly used, the number expressing specific gravity represents the number of times heavier or lighter the liquid under consideration is than an equal volume of water at the same temperature, or to express it as a formula,

$$\text{Sp. G. of any Liquid} = \frac{\text{Weight of a Given Volume of that Liquid}}{\text{Weight of an Equal Volume of Water at same Temp.}}$$

Thus, if 15 cubic centimeters of a sample of sulphuric acid

at 4° C weigh 26.85 grams, and 15 cubic centimeters of water at 4° C 15 grams, then the Sp. G. of the sulphuric acid equals

$$\frac{26.85}{15} = 1.79$$

If 50 cubic centimeters of alcohol at 4° C weigh 40.30 grams, and 50 cubic centimeters of water at 4° C weigh 50 grams, then Sp. G. of the alcohol equals

$$\frac{40.30}{50} = .806$$

When the highest degree of accuracy is desired, the Sp. G. of a liquid is determined by weighing equal volumes of the liquid and water, under the proper conditions, on a delicate balance, using for the container a small capillary stoppered flask, known as a specific gravity bottle, or pycnometer. (See Fig. 16.) For ordinary purposes, however, instruments called hydrometers are used.

Hydrometers (see Fig. 17) are commonly made of glass and consist essentially of: a cylindrical bulb or sealed air-chamber, A (Fig. 18), which gives the instrument sufficient buoyancy to cause it to float in liquids; a long cylindrical stem, C, and a small spherical bulb, B, at the bottom, containing shot or mercury, which brings the center of gravity low enough to keep the stem, C, in an upright position when the hydrometer is placed in a liquid.

The buoyancy or weight-supporting power of a heavy liquid being greater than that of a lighter one, the stem of any particular hydrometer will always extend farther above the surface of a heavy liquid than it will of a lighter one, and the distance to which the stem is exposed will always remain constant for liquids of the same Sp. G. Upon this fact is based the usefulness of the hydrometer.

Hydrometers are graduated in such a way that the Sp. G., in

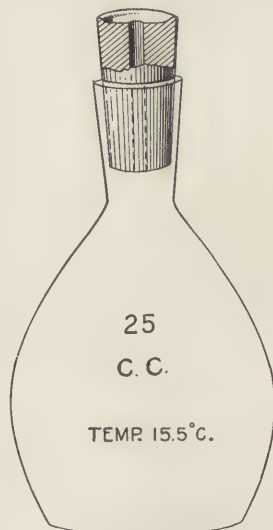


Fig. 16.



some terms or other, can be read directly by observing the marking on the stem coinciding with the surface of the liquid.

Several different systems of graduation are used.

For scientific purposes the regular decimal scale is used, as

Water	=	Sp. G. 1.000
Concent. Sulphuric Acid	=	1.845
Alcohol	=	.806

but in many industrial establishments, and in the chemical trade, the use of other scales which record the Sp. G. in degrees is common.

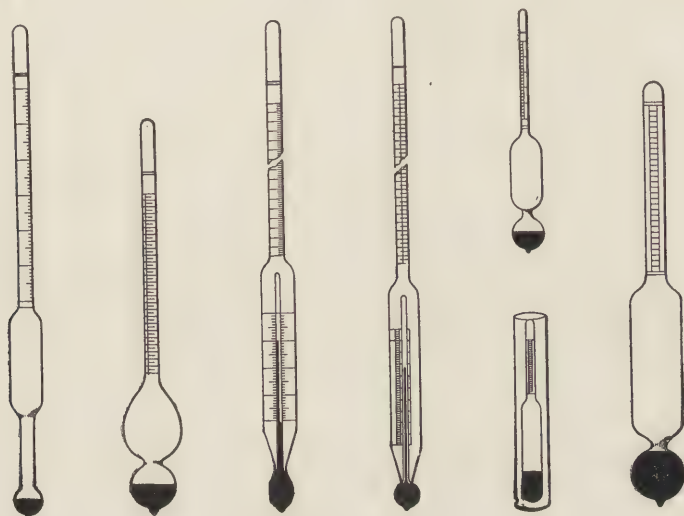


Fig. 17.

Of these scales the Baumé and Twaddle are by far the most important in the United States. The former being used extensively in chemical works and by oil manufacturers, while the latter is in general use in dyehouses, bleacheries and print works.

The Baumé scale, which is arbitrary as far as any exact expression of Sp. G. is concerned, assumes, for liquids heavier than water, the  $0^{\circ}$  on the scale as representing the Sp. G. of pure water, and  $15^{\circ}$  as the Sp. G. of a solution made by dissolving 3 parts of common salt in 17 parts of pure water. The space on the stem between these two points is divided into 15 equal

divisions or degrees, and these divisions are continued as high as 70°.

For liquids lighter than water the length of the division or degree is established by calling the Sp. G. of a solution of 1 part common salt in 9 parts of pure water 0° and pure water 10°.

On hydrometers for liquids heavier than water, the graduation for pure water is at the top of the stem, while for liquids lighter than water it is at the bottom.

On the Twaddle scale, which is also expressed in degrees, one division or degree corresponds to .005 Sp. G.

Thus, water Sp. G. 1.000 =	0° Tw.
Sp. G. 1.005 =	1° Tw.
Sp. G. 1.010 =	2° Tw.
Sp. G. 1.015 =	3° Tw.
Sp. G. 1.250 =	50° Tw.
Sp. G. 1.500 =	100° Tw.

To convert ordinary Sp. G. to degrees Twaddle, subtract 1.000 and divide by .005.

$$\begin{array}{r} \text{Thus, Sp. G. 1.35} = 1.350 \\ \phantom{\text{Thus, Sp. G. 1.35}} \underline{1.000} \\ \phantom{\text{Thus, Sp. G. 1.35}} .005 \overline{) .350} \\ \phantom{\text{Thus, Sp. G. 1.35}} \phantom{.005 \overline{) }} 71^{\circ} \text{ Tw.} \end{array}$$

To convert degrees Twaddle into Sp. G., multiply by .005 and add 1.000.

$$\begin{array}{r} \text{Thus, } 71^{\circ} \text{ Tw.} = 71 \times .005 = .355 \\ \phantom{\text{Thus, } 71^{\circ} \text{ Tw.} = } \underline{1.000} \\ \phantom{\text{Thus, } 71^{\circ} \text{ Tw.} = } 1.355 = \text{Sp. G.} \end{array}$$

For the conversion of Beaumé degrees into Twaddle degrees or actual specific gravity readings, or *vice versa*, a table is necessary.

Table A, see page 44, will be found handy for reference and conversion.

The great value of the hydrometer lies in the simplicity with which the instrument may be used for determining the strength of various acids and solutions of chemicals.



Fig. 18.

In general, the Sp. G. of a solution of a substance or mixture of an acid with water increases as the ratio of the amount of substance or acid to the amount of water increases.

For a given amount of any substance dissolved in a given amount of pure water, however, the Sp. G. remains constant.

Thus the Sp. G. of an 8 per cent solution of caustic soda = 1.091, and of a 40 per cent solution of caustic soda = 1.438.

These amounts remaining constant at the temperature at which they were determined, all that is necessary, if we wish to make up an 8 per cent or 40 per cent solution, is to add caustic soda to water, until the hydrometer registers the corresponding Sp. G.

Tables have been carefully prepared which give the Sp. Gravities corresponding to various percentage strengths of solutions of all the common chemicals and acids, and to determine the strength of such a solution it is only necessary to take the hydrometer reading and consult the table.

Many books containing Sp. G. tables exist, and one should be kept with the necessary hydrometers and cylinders in every well-regulated dyehouse.

Table B, see page 44 for caustic soda, will serve as a good example.

For a mixture of water with a liquid that is lighter, as alcohol, the Sp. G. diminishes as the ratio of the liquid to the water increases. The Sp. G. of the solutions of certain gases in water, as ammonia, also diminishes as the percentage of gas dissolved increases.

As already stated, the standard temperature for testing liquids by hydrometers is 60° F or 15.5° C. Hydrometers are graduated for this temperature, and for accurate work liquids should always be brought to the standard temperature. If the temperature of liquids heavier than water is above 60° F, the reading will be too low, and if below, the reading will be too high. For liquids lighter than water the reverse will be the case. The hydrometers supplied by the makers are often inaccurate, and should be tested by comparison with the specific gravity bottle or with hydrometers known to be correct.

The Beaumé hydrometer is founded on an arbitrary standard, which varies in Europe and America. The readings of the American standard are slightly below those of the English standard. This fact should be noted when using tables.



TABLE A.

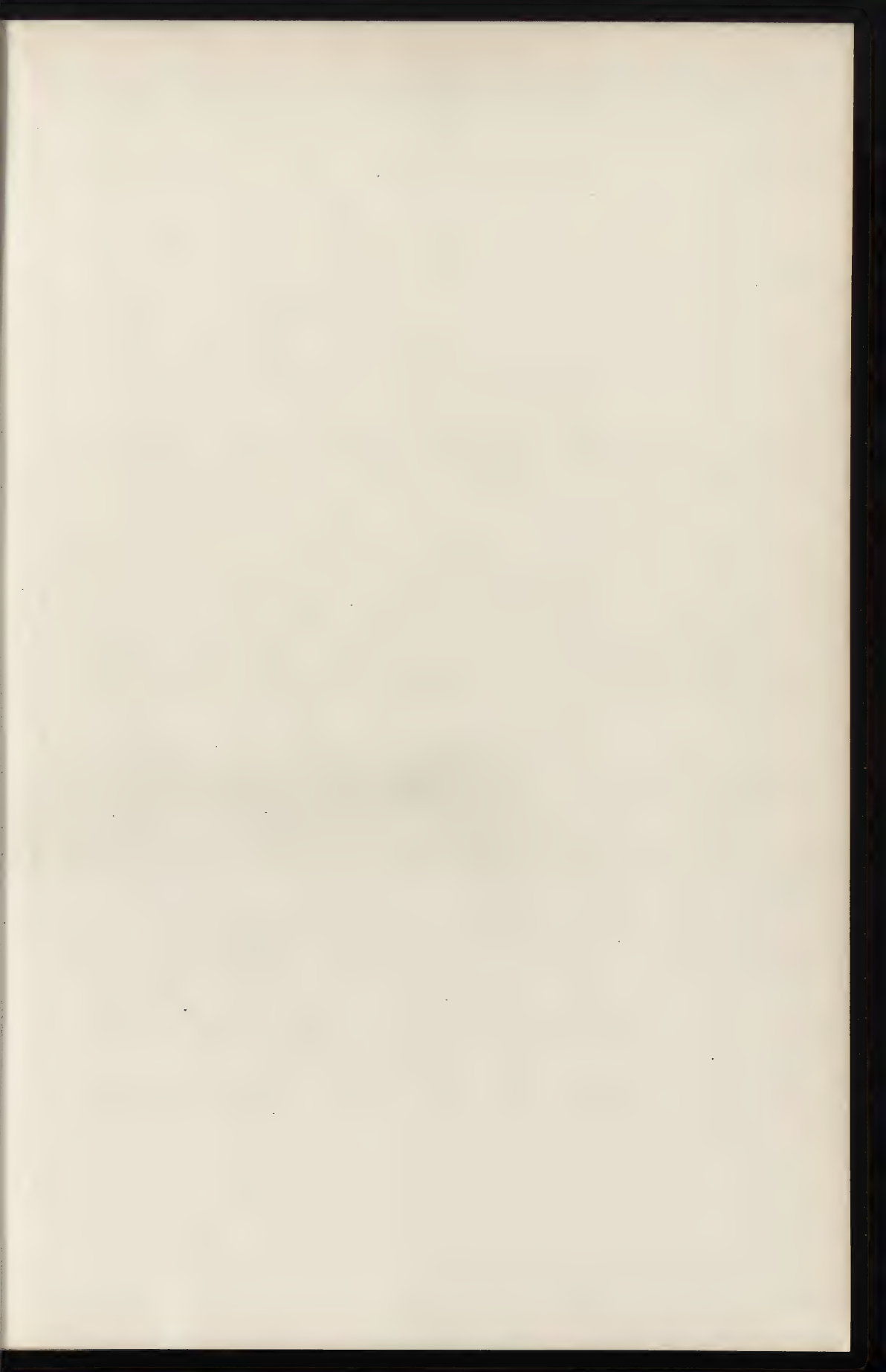
SPECIFIC GRAVITY, DEGREES TWADDLE AND DEGREES BEAUME.

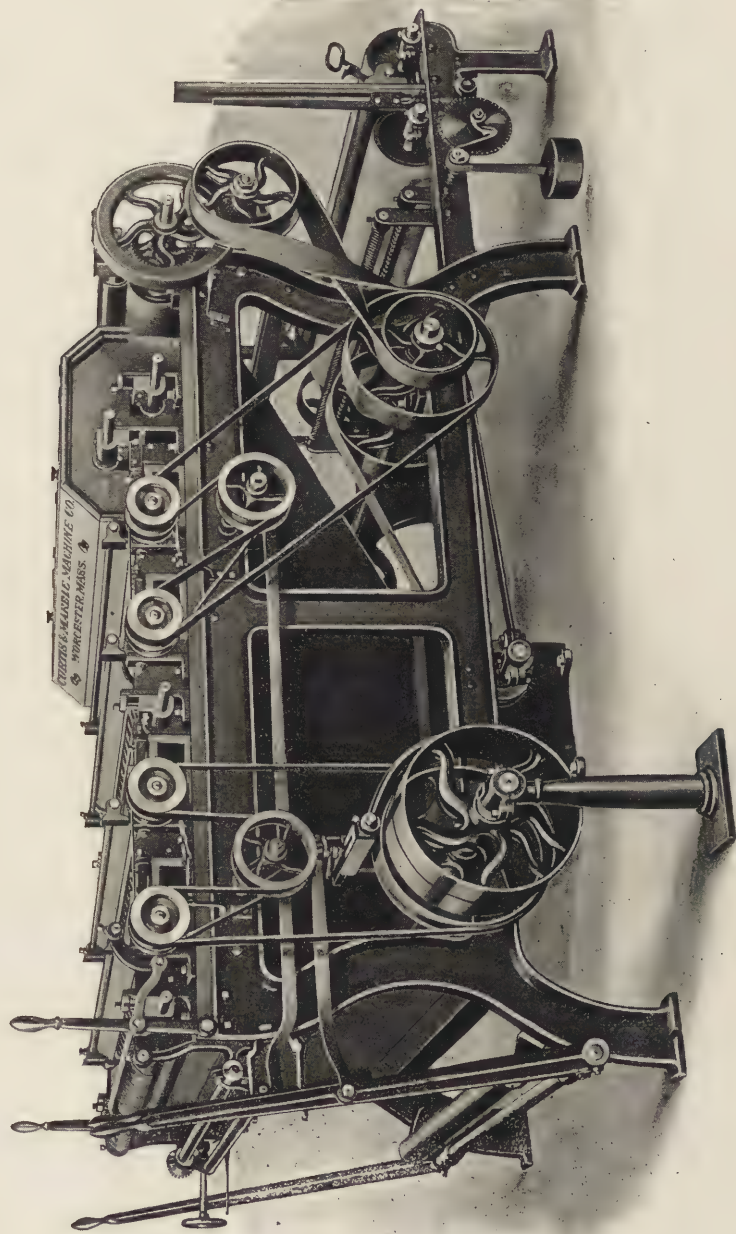
Twaddle.	Beaumé.	Specific gravity.	Twaddle.	Beaumé.	Specific gravity.	Twaddle.	Beaumé.	Specific gravity.	Twaddle.	Beaumé.	Specific gravity.
0	0	1.000	44	26.0	1.220	88	44.1	1.440	132	57.4	1.660
1	0.7	1.005	45	26.4	1.225	89	44.4	1.445	133	57.7	1.665
2	1.4	1.010	46	26.9	1.230	90	44.8	1.450	134	57.9	1.670
3	2.1	1.015	47	27.1	1.235	91	45.1	1.455	135	58.2	1.675
4	2.7	1.020	48	27.9	1.240	92	45.4	1.460	136	58.4	1.680
5	3.4	1.025	49	28.4	1.245	93	45.8	1.465	137	58.7	1.685
6	4.1	1.030	50	28.8	1.250	94	46.1	1.470	138	58.9	1.690
7	4.7	1.035	51	29.3	1.255	95	46.4	1.475	139	59.2	1.695
8	5.4	1.040	52	29.7	1.260	96	46.8	1.480	140	59.5	1.700
9	6.0	1.045	53	30.2	1.265	97	47.1	1.485	141	59.7	1.705
10	6.7	1.050	54	30.6	1.270	98	47.4	1.490	142	60.0	1.710
11	7.4	1.055	55	31.1	1.275	99	47.8	1.495	143	60.2	1.715
12	8.0	1.060	56	31.5	1.280	100	48.1	1.500	144	60.4	1.720
13	8.7	1.065	57	32.0	1.285	101	48.4	1.505	145	60.6	1.725
14	9.4	1.070	58	32.4	1.290	102	48.7	1.510	146	60.9	1.730
15	10.0	1.075	59	32.8	1.295	103	49.0	1.515	147	61.1	1.735
16	10.6	1.080	60	33.3	1.300	104	49.4	1.520	148	61.4	1.740
17	11.2	1.085	61	33.7	1.305	105	49.7	1.525	149	61.6	1.745
18	11.9	1.090	62	34.2	1.310	106	50.0	1.530	150	61.8	1.750
19	12.4	1.095	63	34.6	1.315	107	50.3	1.535	151	62.1	1.755
20	13.0	1.100	64	35.0	1.320	108	50.6	1.540	152	62.3	1.760
21	13.6	1.105	65	35.4	1.325	109	50.9	1.545	153	62.5	1.765
22	14.2	1.110	66	35.8	1.330	110	51.2	1.550	154	62.8	1.770
23	14.9	1.115	67	36.2	1.335	111	51.5	1.555	155	63.0	1.775
24	15.4	1.120	68	36.6	1.340	112	51.8	1.560	156	63.2	1.780
25	16.0	1.125	69	37.0	1.345	113	52.1	1.565	157	63.5	1.785
26	16.5	1.130	70	37.4	1.350	114	52.4	1.570	158	63.7	1.790
27	17.1	1.135	71	37.8	1.355	115	52.7	1.575	159	64.0	1.795
28	17.7	1.140	72	38.2	1.360	116	53.0	1.580	160	64.2	1.800
29	18.3	1.145	73	38.6	1.365	117	53.3	1.585	161	64.4	1.805
30	18.8	1.150	74	39.0	1.370	118	53.6	1.590	162	64.6	1.810
31	19.3	1.155	75	39.4	1.375	119	53.9	1.595	163	64.8	1.815
32	19.8	1.160	76	39.8	1.380	120	54.1	1.600	164	65.0	1.820
33	20.3	1.165	77	40.1	1.385	121	54.4	1.605	165	65.2	1.825
34	20.9	1.170	78	40.5	1.390	122	54.7	1.610	166	65.5	1.830
35	21.4	1.175	79	40.8	1.395	123	55.0	1.615	167	65.7	1.835
36	22.0	1.180	80	41.2	1.400	124	55.2	1.620	168	65.9	1.840
37	22.5	1.185	81	41.6	1.405	125	55.5	1.625	169	66.1	1.845
38	23.0	1.190	82	42.0	1.410	126	55.8	1.630	170	66.3	1.850
39	23.5	1.195	83	42.3	1.415	127	56.0	1.635	171	66.5	1.855
40	24.0	1.200	84	42.7	1.420	128	56.3	1.640	172	66.7	1.860
41	24.5	1.205	85	43.1	1.425	129	56.6	1.645	173	67.0	1.865
42	25.0	1.210	86	43.4	1.430	130	56.9	1.650			
43	25.5	1.215	87	43.8	1.435	131	57.1	1.655			

TABLE B.

SPECIFIC GRAVITY OF CAUSTIC SODA AT 15° (LUNGE).

Specific gravity.	Beaumé.	Twaddle.	Per cent Na <sub>2</sub> O	Per cent NaOH	Specific gravity.	Beaumé.	Twaddle.	Per cent Na <sub>2</sub> O	Per cent NaOH
1.007	1	1.4	0.47	0.61	1.220	26	44.0	15.18	19.58
1.014	2	2.8	0.93	1.20	1.231	27	46.2	15.96	20.59
1.022	3	4.4	1.55	2.00	1.241	28	48.2	16.76	21.42
1.029	4	5.8	2.10	2.71	1.252	29	50.4	17.55	22.64
1.036	5	7.2	2.60	3.35	1.263	30	52.6	18.35	23.67
1.045	6	9.0	3.10	4.00	1.274	31	54.8	19.23	24.81
1.052	7	10.4	3.60	4.64	1.285	32	57.0	20.00	25.80
1.060	8	12.0	4.10	5.29	1.297	33	59.4	20.80	26.83
1.067	9	13.4	4.55	5.87	1.308	34	61.6	21.55	27.80
1.075	10	15.0	5.08	6.55	1.320	35	64.0	22.35	28.83
1.083	11	16.6	5.67	7.31	1.332	36	66.4	23.20	29.93
1.091	12	18.2	6.20	8.00	1.345	37	69.0	24.20	31.22
1.100	13	20.0	6.73	8.68	1.357	38	71.4	25.17	32.47
1.108	14	21.6	7.30	9.42	1.370	39	74.0	26.12	33.69
1.116	15	23.2	7.80	10.06	1.383	40	76.6	27.10	34.96
1.125	16	25.0	8.50	10.97	1.397	41	79.4	28.10	36.25
1.134	17	26.8	9.18	11.84	1.410	42	82.0	29.05	37.47
1.142	18	28.4	9.80	12.64	1.424	43	84.8	30.08	38.80
1.152	19	30.4	10.50	13.55	1.438	44	87.6	31.00	39.99
1.162	20	32.4	11.14	14.37	1.453	45	90.6	32.10	41.41
1.171	21	34.2	11.73	15.13	1.468	46	93.6	33.20	42.83
1.180	22	36.0	12.33	15.91	1.483	47	96.6	34.40	44.38
1.190	23	38.0	13.00	16.77	1.498	48	99.6	35.70	46.16
1.200	24	40.0	13.70	17.67	1.514	49	102.8	36.90	47.60
1.210	25	42.0	14.40	18.58	1.530	50	106.0	38.00	49.02





COTTON SHEARING MACHINE DESIGNED FOR PRINTERIES, BLEACHERIES, ETC.

Curtis & Marble Machine Co.



# TEXTILE CHEMISTRY AND DYEING.

## PART II.

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### OPERATIONS PRELIMINARY TO DYEING.

**87. Necessity of a Preliminary Treatment of Textile Material and the Three Stages of the Manufacturing Process during which this Treatment may be Performed.** All fibers contain a varying amount of impurities both natural and foreign. These must be removed before the fibers are of such a character as to be used for the production of white goods or to be dyed delicate tints or light shades. This necessitates that most textile materials be given certain preliminary treatments before they can be used for the above purposes.

These preliminary treatments may be given:—

1st. When the fiber is in the loose or unspun state, as is customary with wool.

2d. When it has been spun and is in the form of yarn as is the case with silk.

3d. When it has been woven and is in the form of cloth, as is commonly the case with cotton.

### COTTON BLEACHING.

**88. Natural Impurities of Cotton.** It has previously been stated (See No. 13) that the approximate composition of raw cotton is,

Cellulose	87 to 90%
Water	5 to 7%
Natural Impurities	4 to 6%

These natural impurities are for the most part insoluble in water, but may be removed by the use of certain acids and alkalis. If we boil unbleached cotton in a clear solution of soda ash, the solution gradually assumes a dark brown color. By adding sulphuric acid to this solution a dark colored flocculent precipitate is thrown down which contains the greater portion of natural impurities. (See No. 16.)

**89. Foreign Impurities in Cotton.** Beside containing natural impurities, cotton that has been made into yarn or cloth, picks up from the various machines through which it passes and from the hands of the operatives, a varying amount of foreign dirt and grease. Furthermore a varying amount of sizing material, composed largely of organic matter is added to the warp previous to the process of weaving, and the cloth when it arrives at the bleachery invariably has a grayish and dirty appearance, and the total amount of impurities may run as high as 30% of the weight of the cloth.

**90. Object of Bleaching.** Cotton bleaching has for its object the complete removal of these natural and foreign impurities, in order that the cloth may be sold in a pure white state and to prepare it for the dyeing of delicate tints or light shades, or the production of perfectly white grounds in calico printing. The bleaching of *back cloths* is also an important consideration. In calico printing it is customary to print on bleached cotton cloth, constantly keeping between this cloth and the padding blanket, a piece of unbleached or gray cloth which owing to the shrinkage in bleaching is several inches wider than the bleached piece that is being printed. This intermediate piece of cloth is known as the *back cloth* and serves to protect the blanket from any color that may strike through or lap over the printed cloth.

Three general principles are commonly involved in the accomplishment of these results; 1st, the removal of such impurities as are soluble in water, by simple washing; 2d, the conversion of others by the action of various chemical reagents into compounds soluble in water, which are then easily removed by subsequent washing, and finally the decolorization of any remaining impurities which have resisted previous treatment.

**91. Three States in which Cotton may be Bleached.** It is possible to bleach cotton in the three states, namely, raw or loose state, in the form of yarn, or as cotton cloth or piece goods. The latter will be considered first.

**92. Bleaching of Cotton Piece Goods. General Consideration.** By far the most important and extensively used form of cotton bleaching is that of woven cloth commonly called piece goods.

The bleaching of cotton cloth is rendered more complicated and laborious, than that of cotton yarn or raw cotton, for the two latter contain little other than natural impurities, while the cotton cloth contains a high percentage of foreign impurities introduced during the process of weaving, by oily machinery, greasy hands, and to a still greater extent in the form of warp sizing. The following are some of the substances that may be used in sizing; farina, starch, soap, tallow, paraffin wax, small quantities of copper and lime soaps, and certain inorganic compounds such as the sulphates of magnesium and barium and the chlorides of magnesium and zinc. The total impurities in the woven cloth may amount to as high as 25 to 30%. Not only do all these impurities have to be removed, but in many cases the back cloths (See No. 90), which may be daubed with any of the colors used in a print works, have to be bleached.

Different bleachers have different ideas in regard to bleaching and it is doubtful if two bleacheries, not under the same management, could be found using the same process in every detail. It is only the detail however that varies, for the principles involved have remained the same for more than a half century.

The almost universal bleaching agent for cotton is chlorine, it commonly being liberated from bleaching powder or calcium hypochlorite during the bleaching process.

The bleaching proper is usually preceded by boiling the material in one or more alkaline baths to facilitate the removal of those impurities which the chlorine would not destroy. In addition several treatments with dilute acid, and thorough washings are necessary at various stages of the process.

**93. Grades of Bleaching.** There are several grades of



bleached cotton cloth which differ chiefly in the thoroughness with which the bleaching has been carried out. As examples we have,

- (1). *Madder Bleach, which is the commonest.*
- (2). *Turkey Red Bleach.*
- (3). *Market Bleach.*
- (4). *Rapid Bleach, where the cloth is to be dyed a dark shade.*

The bleach applied in any particular case, depends upon the manner in which the cloth is to be finished or subsequently used. Each will be treated separately beginning with the madder bleach, the process for which will be given in detail including a description of the apparatus used. The others will be given with only sufficient detail to show wherein they differ from the madder bleach.

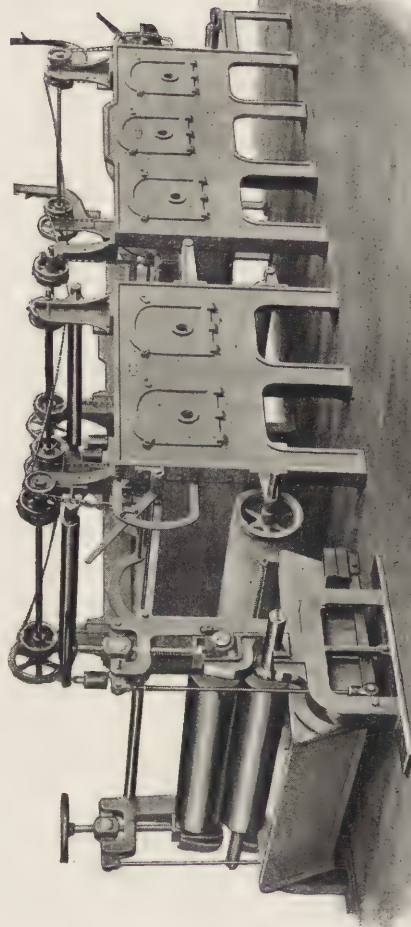
**94. The Madder Bleach.** (*Origin of Name and when used.*) In the days when madder was so extensively used, it was customary to give cloth printed with that dye stuff an extremely thorough bleach. At the present time madder has been entirely replaced by other dye stuffs, especially the alizarines, but the name Madder Bleach is still used in many bleacheries, and we will use it to represent the most thorough form of bleaching in use to-day for cotton piece goods. The process has been changed but little since its introduction, about the year 1835.

In calico printing with alizarine colors, or in fact any colors, where a particularly clear and white ground is desired this form of bleach is used.

**95. Outline of the Madder Bleach.** The following may be taken as an outline of the steps in the Madder Bleach.

- (1). Stamping and Stitching.
- (2). Singeing and Shearing.
- (3). Wash following singeing. (Gray Wash.)
- (4). Lime Boil.
- (5). Wash.
- (6). Acid Treatment. (Sometimes called the Brown Sour.)
- (7). Wash.





SINGEING MACHINE, OIL FUEL  
H. W. Butterworth & Sons Co.



- (8-9). Lye Boils. (Resin Soap and Alkali.)
- (10). Wash.
- (11). Chemicking or Bleaching Proper.
- (12). Wash.
- (13). Acid Treatment. (Sometimes called White Sour.)
- (14). Final Wash.
- (15). Finishing.

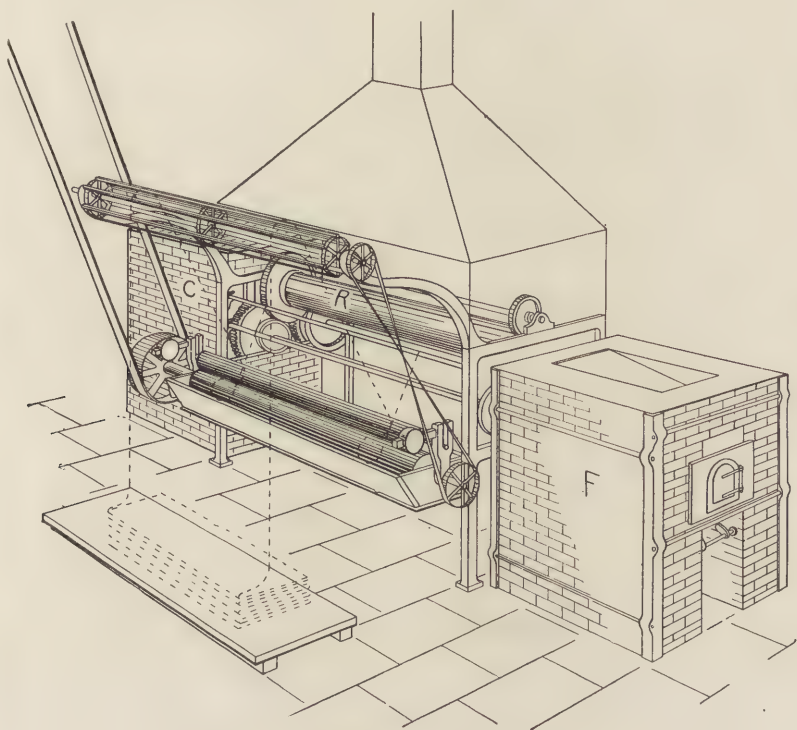


Fig. 19. Roller Singeing Machine.

**96. Stamping and Stitching.** Each separate piece of cloth as it is taken from the bale or roll, is stamped with a system of letters and figures, so that it can be identified at any time during the subsequent processes. In the stamping, some substance such as coal tar or aniline black must be used which will not be destroyed during the bleaching.

These pieces of cloth, which contain in the neighborhood of fifty yards each, are placed end to end and stitched together on a

portable sewing machine. As many as 800 pieces are sometimes fastened together in this way making a continuous strip 4,000 yards or nearly 25 miles long. Such a piece is called a "lot."

**97. Shearing and Singeing.** The surface of the gray cloth always possesses more or less unevenness owing to loose threads and projecting notes; also a fuzziness or nap, all of which must be removed before the surface possesses the necessary smoothness for printing. With this in view the gray cloth is always subjected

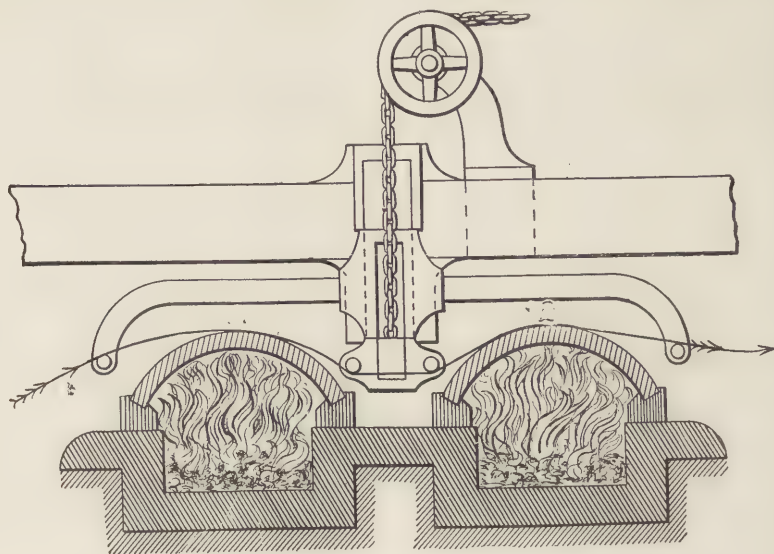


Fig. 20. Principle of Plate Singeing.

to the singeing operation, and not unfrequently passed through a shearing machine. When both machines are used, the cloth passes through the shearing machine which removes the large threads and heavier nap and then through the singeing machine which takes off the lighter nap and clears the fabric. A combination machine to perform both operations is sometimes used.

The principle of the singeing is to pass the cloth over heated metallic rolls or plates, or through a series of gas flames, at such a speed as to allow the surface inequalities and nap to be burned off without burning the body of the fabric.

In the roller singeing machine (See Fig. 19) the cloth is passed in the full width over a hollow roller R that is kept at a red

heat by the passage of the flame from the furnace F, through it to the chimney C.

The principle of the plate singeing will be easily understood from Fig. 20. The plates are usually of copper and may be heated by coal, petroleum, or gas. Fig. 21 shows a plate singer in operation.

Gas singeing machines vary somewhat in construction, but (Fig. 22) will serve as a good illustration. The cloth is passed full width through one or more series of gas flames, coming

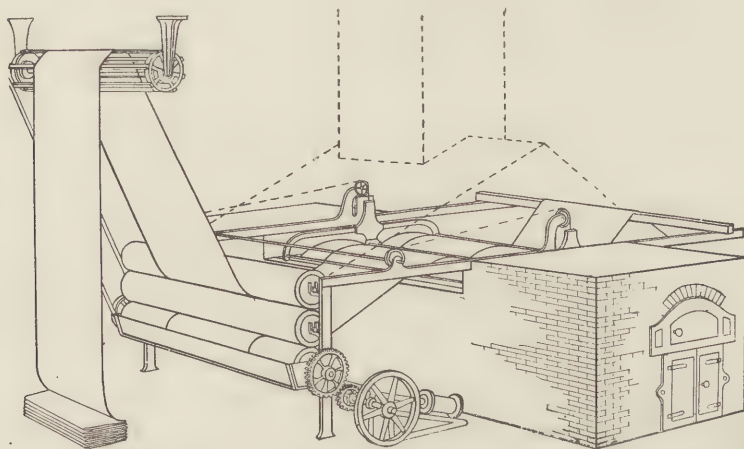


Fig. 21. Plate Singer in Operation.

from rows of Bunsen burners. The principle will be easily understood from Figs. 23 and 24. The flames come in contact with the cloth while the latter is being passed with considerable tension over the rolls N N. This causes the nap to stand out as much as possible. B in Fig. 23 represents the end burner of the series, and H a hood through which a draught is constantly passing.

Upon leaving the singeing machine the cloth is often passed rapidly through water, or a steam box, in order to extinguish any sparks that might remain upon the surface.

Concerning the relative value of plate and gas singeing, it may be said that with the former the surface is very thoroughly singed, with little if any singeing between the threads; while with gas singeing there is less action upon the surface, but greater



penetration between the threads. By many, plate singeing is considered better for heavy goods, and gas singeing more desirable for light fabrics and those of comparatively open weave, and also raised figure goods, and corduroys on account of the unevenness of their surface. For some classes of sateens plate singeing is probably better as it gives a desirable rub finish to the goods.

Machines combining both gas and plate singeing are sometimes used. Fig. 25 represents a type of combination machine

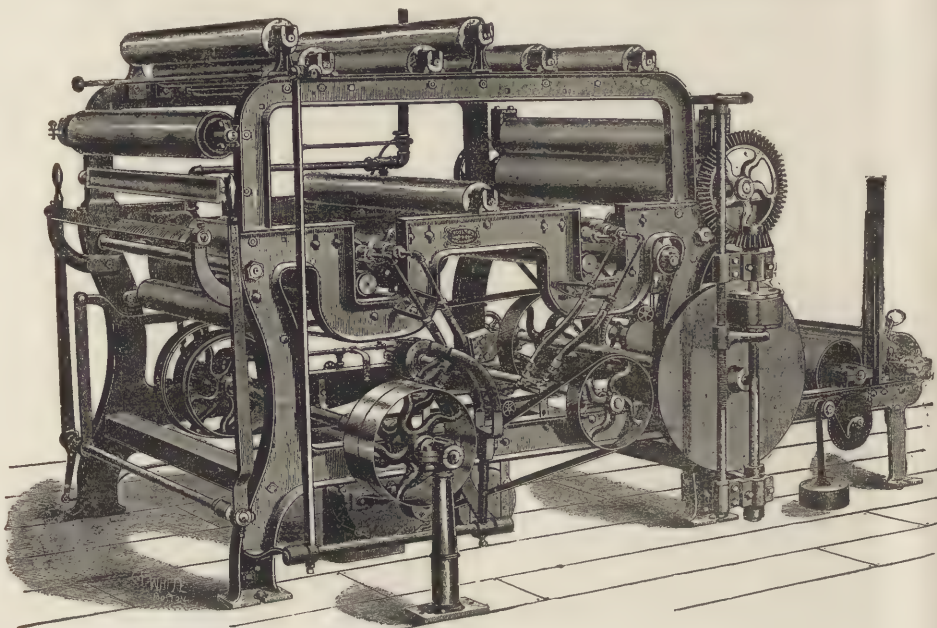


Fig. 22. Elevation of Singeing Machine.

made by the Granger Foundry and Machine Co. of Providence. The plates in this machine are heated by petroleum, and rows of flames from the same fuel placed between the plates.

The whole singeing room should be well ventilated, and it is advisable to furnish each machine with a separate hood and forced draught.

Any excess of nap remaining after the bleaching must be removed by shearing, since singeing can never be done successfully after bleaching, owing to the more or less scorched or brown color it imparts to the cloth.

The extent to which the shearing is carried out and the period of the operation at which it is performed, depends upon the nature of the cloth and the uses to which it is to be put.

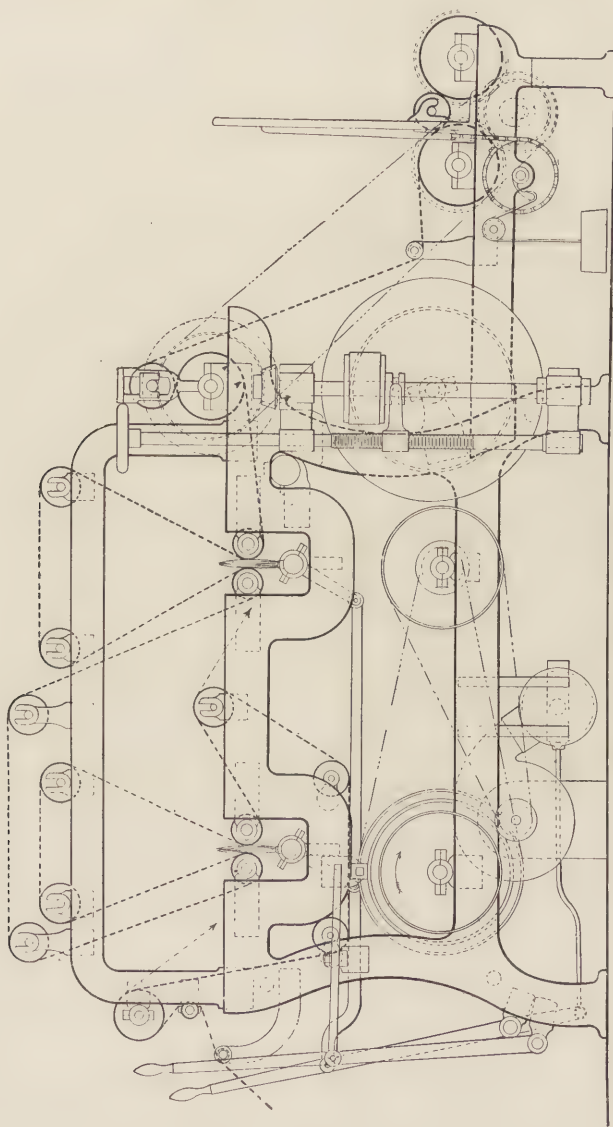


Fig. 22 A. Sectional View of Fig. 22.

The shearing machine consists of a set of very sharp steel blades spirally set into a roller which revolves rapidly, near and

parallel to a stationary blade, the whole resembling an inverted lawn mower. (See Fig. 26 B.) The shearing is accomplished by passing the cloth full width between the stationary and the revolving blades. The shearing machines are also equipped with rapidly revolving brushes, which serve to bring out the nap before

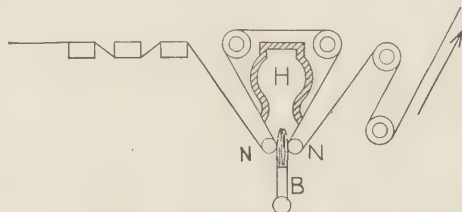


Fig. 23.

the shearing and remove the loose fuzz and dust that collects upon the surface of the cloth.

One of the standard types of Cotton Shearing Machines for bleacheries built by the Curtis and Marble Machine Co. is shown at Fig. 26. This is made with four sets of shear blades for the face and with brushes for the face and back of the goods; three

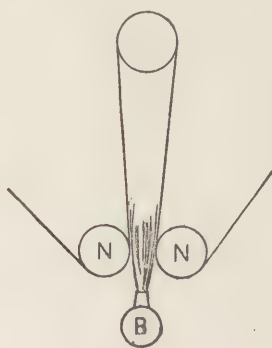


Fig. 24.

for the face and one for the back. This machine applies especially to those cotton fabrics where but one side of the cloth is to be sheared. The one or more brushes which apply on the back of the goods are especially valuable since the face and back of the cloth comes in contact with each other when rolled up; so that if dirt or lint be left on the back it is liable to come off on the face when the goods are unrolled, thus giving trouble in the subsequent processes. Shearing machines are made with from four to six sets of shear blade for the

face, and any number of brushes for both face and back, according to the requirements of the class of work in hand.

Fig. 26 A is a sectional view of this machine showing the threading of the cloth, swing cloth-rests and stop motion for the revolvers. It will thus be seen that the cloth-rests may be raised



or the revolvers stopped in order to allow the seams to pass through. The exhaust fan underneath the machine provides means for carrying away dust and lint. This shear may be operated from either side as regards starting and stopping and the

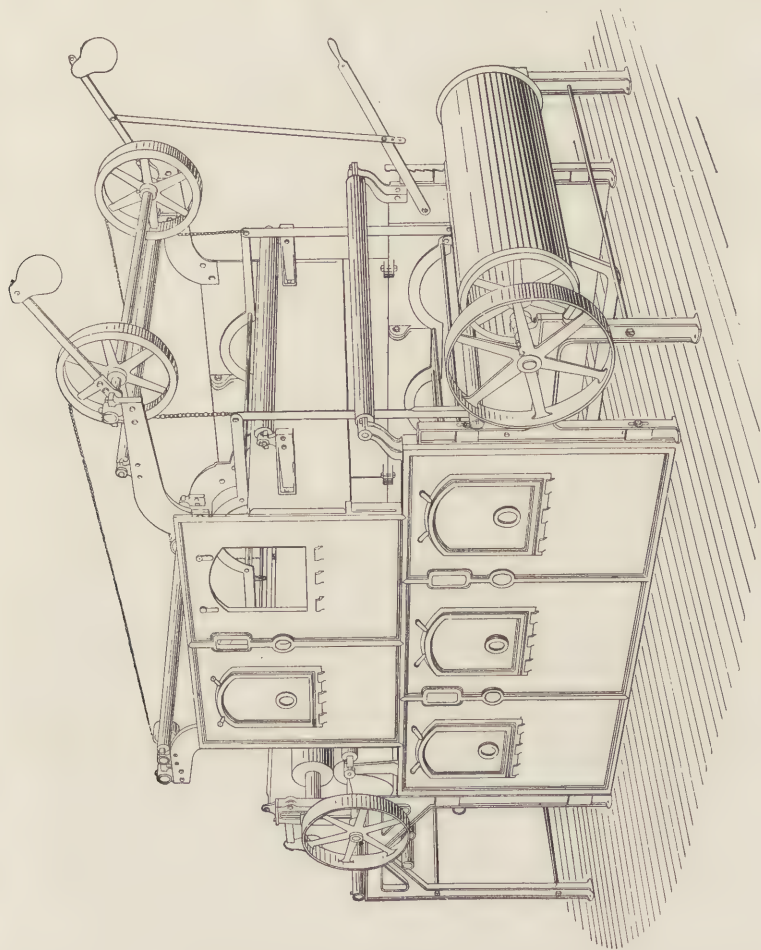


Fig. 25. Combination Plate and Gas Singer.

lifting of the cloth-rests or stopping of the revolvers. Spreader bars are attached to both the front and delivery ends for taking out wrinkles and turned edges ; these together with the horizontal rolling attachment, causes a smooth even roll to be delivered after shearing.

A simple form of English shearing machine made by Mather

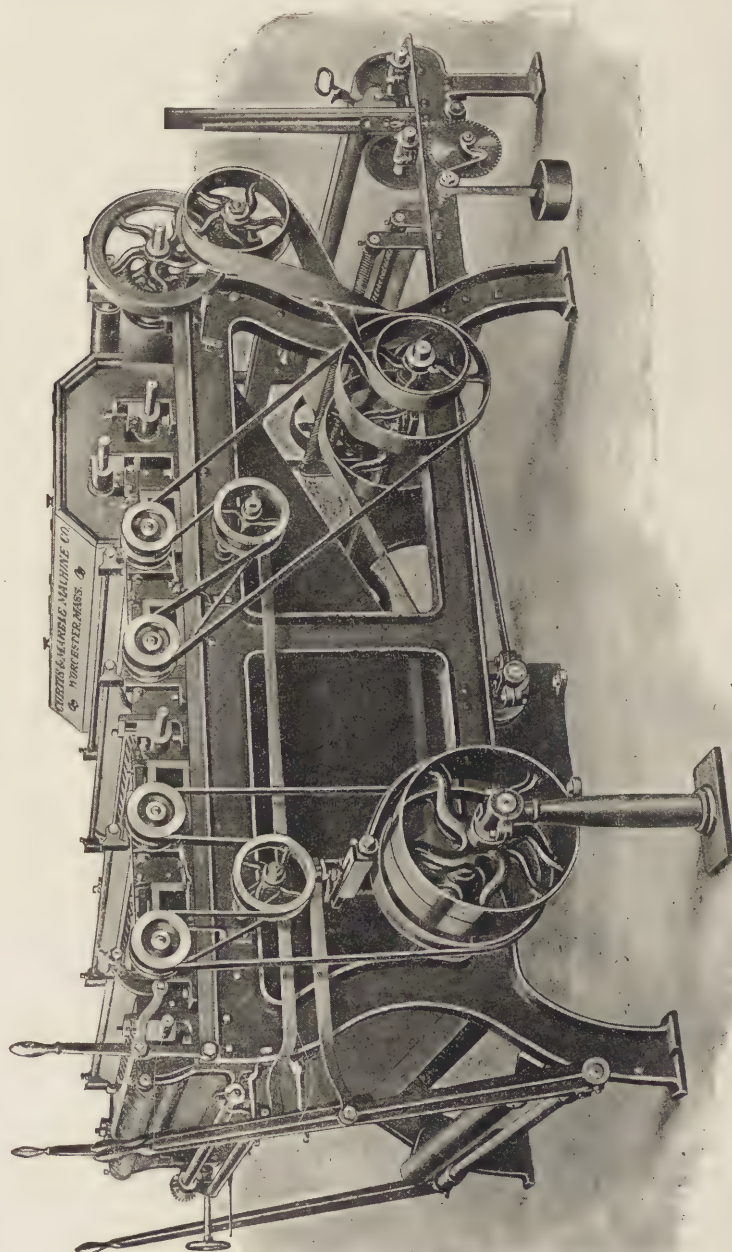


Fig. 26. Elevation of Cotton Shearing Machine.

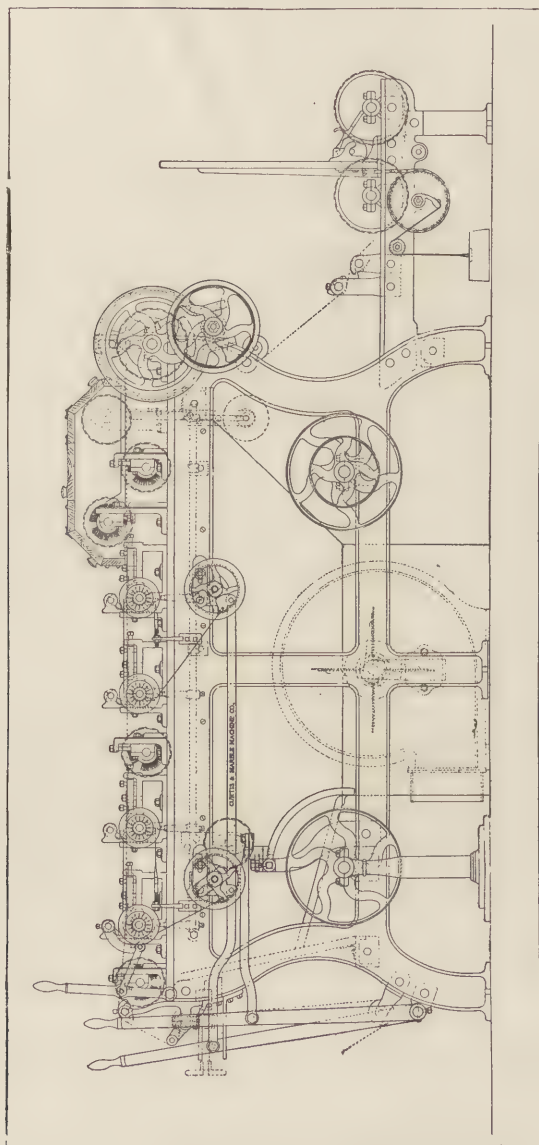


Fig. 26 A. Sectional View of Fig. 26.



& Platt is represented in Fig. 27. This machine is used in cotton print works and bleacheries, where it is necessary to shear but one side of the cloth.

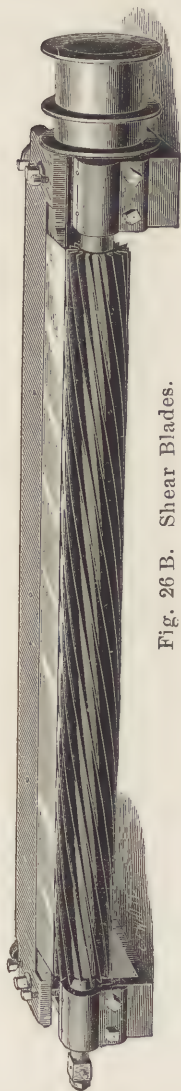


Fig. 26 B. Shear Blades.

#### 98. The Gray Wash and its Chemistry.

Upon leaving the singeing room the cloth is ready for the gray wash, the first step in the actual bleaching process. It is at this stage that the cloth passes from the full width to the rope or string form, as it is called, which form it retains until the bleaching process is completed. This is accomplished (See Fig. 28) by simply allowing the cloth to pass directly from the roll through a smooth porcelain or hard rubber ring (sometimes called a pot eye), about 6 inches in diameter.

The gray wash is usually accomplished by first running the cloth through water in an ordinary washing machine (See Figs. 29 and 30) and then allowing it to stand in the wet or at least damp condition for several hours or even over night.

The object of this washing is to remove everything present in the cloth that is soluble in water, and to attack the surface coating, so that the fiber may become thoroughly wet out and penetrable by liquids. When crowded for room or pushed for time, the cloth may be passed from the washing machine directly through squeeze rolls and into the kier in which the next step of the operation is performed, but it is an established fact that an exposure of cloth to the air in a moist condition for a number of hours renders the remaining impurities more easily removed in the subsequent operations. This is probably due to a mild fermentation of the sizing materials and some of the natural impurities present.

Some bleachers recommend a steeping process in which the water is warmed to between 50° and 60° C. (122° — 140° F.) for

a number of hours. Under these conditions the surface coating of the fiber seems to be more energetically attacked. When the lime boil follows, this steeping process is scarcely necessary, but in such processes as the Mather and Platt (See No. 120) where the lime boil is entirely omitted, and in some forms of linen bleaching, it seems advantageous.

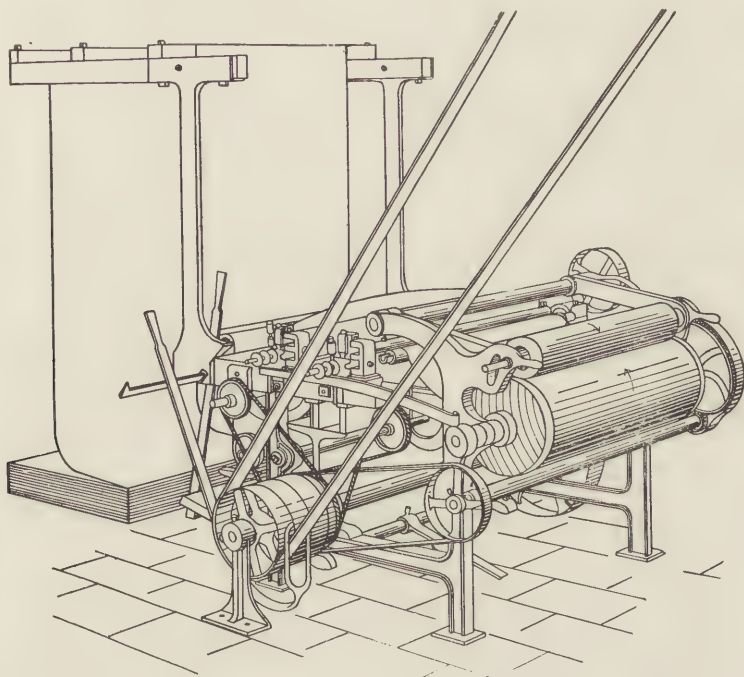
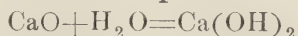


Fig. 27. Mather and Platt Shear.

**99. Lime Boil.** The lime boil follows the gray wash and consists in boiling, or to use the term of the works, "BOWKING" the cloth in a solution of lime water, calcium hydroxide  $\text{Ca}(\text{OH})_2$ , for a number of hours in an especially constructed boiler known as a kier. (For description of kiers See No. 100.)

The quick lime used should be perfectly white, as nearly pure calcium oxide as possible, and free from iron. If stored before use, care should be taken not to expose it to the air, or it will become air-slaked or carbonated.

The lime is often slaked with water in a wooden bin or box, where the following reaction takes place:



Quick Lime + Water = Calcium Hydroxide or Water Slaked Lime.

The Calcium Hydroxide thus formed is of a damp powdery nature, and when mixed with a little water makes a thick paste of a creamy consistency. This is then worked through a sieve into a special mixing apparatus, which commonly consists of an iron tank provided with a mechanical agitator. The sieve should be

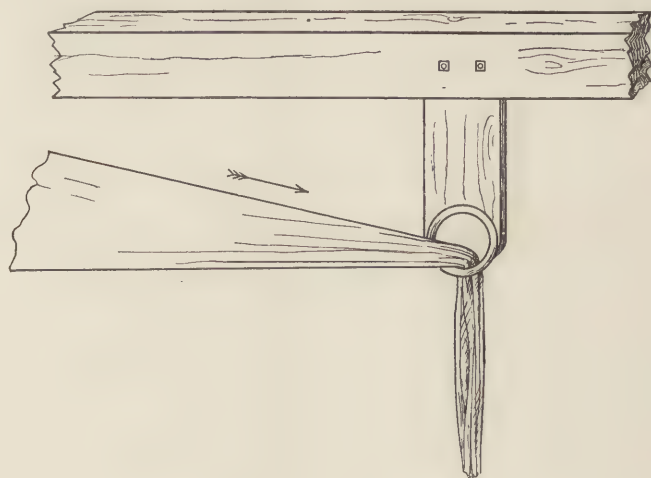


Fig. 28. Pot Eye.

of such a sized mesh as to completely remove any lumps or particles of quick lime or unslaked lime, for these would tender the cloth if they came in contact with it at the high temperature of the kiers.

Calcium hydroxide is not extremely soluble in water, and the liquor issuing from the mixing apparatus is not a clear lime water, but a so-called milk of lime having a milky white appearance due to the presence of a large amount of finely divided calcium hydroxide held in suspension.

The milk of lime is run directly into the box or pit of the liming machine, a very common form of which is represented in Figs. 31 A and 32 A. The cloth passes directly through the lime



pit A. where it is saturated, and after the excess of liquor has been removed by the squeeze roll B.B., it passes directly into the kier.

The quantity of lime used varies according to the material being bleached, from 3 to as high as 10% of the weight of the material being bleached. For print cloths, however, the amount is commonly from 4 to 6%. Some bleachers think it advan-

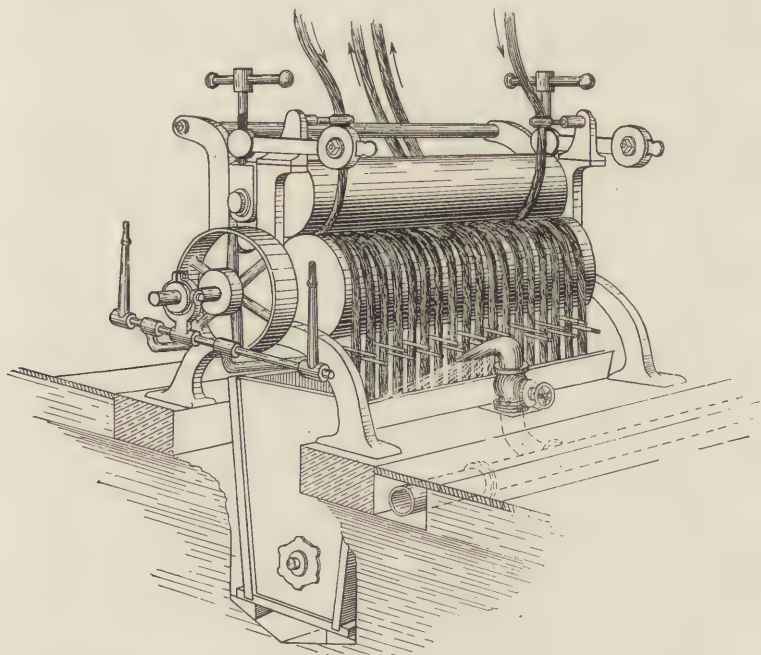


Fig. 29. Washing Machine.

tageous to add a small quantity, say one pail full of 50° Twaddle caustic soda solution to the kier after it has been filled.

#### KIERS.

**100.** To give an account and description of the numerous bleaching kiers that have been used would, even if possible, require much space and be of but little value. We will therefore speak only of the most important forms and give descriptions of some of these in use at the present time.

In general, kiers may be divided into two classes:

- (1). Open or Low Pressure Kiers.
- (2). Closed or Pressure Kiers.

**Open Kiers.** One of the oldest forms of open kiers is represented in Fig. 33. It consists of a cylindrical vessel either of iron or wood, 9 or 10 feet in diameter, provided with a false or

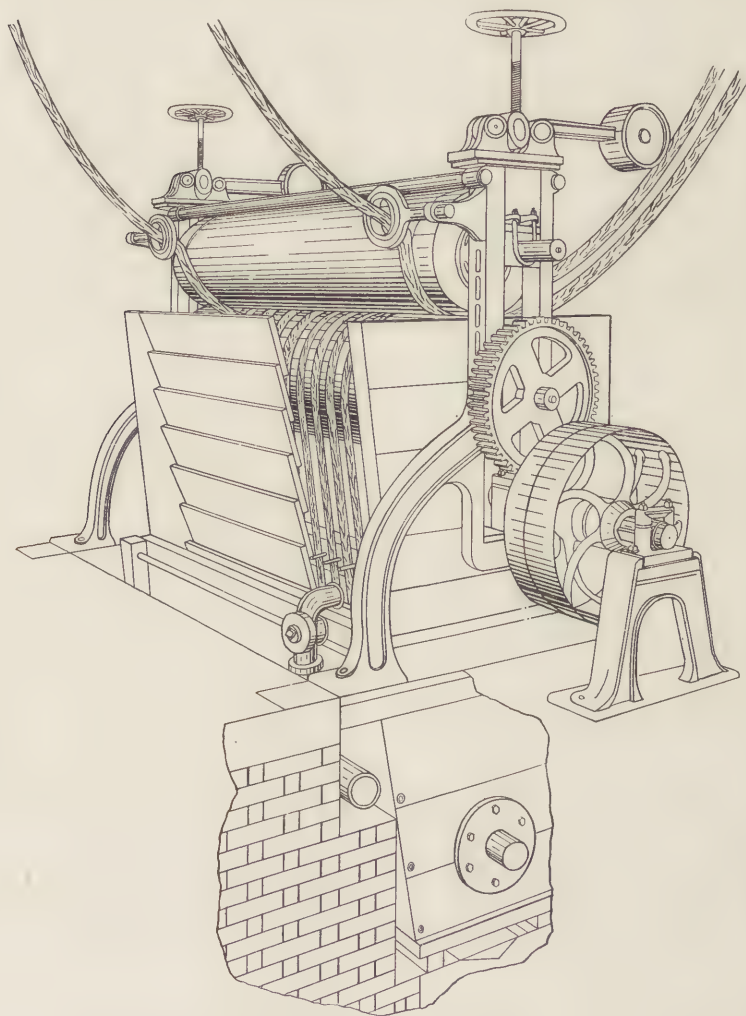


Fig. 30. Washing Machine.

perforated bottom AA, about 18 inches above the true bottom. It contains a large center pipe or well BB, which is open at the bottom C, and at the top D. Through this large pipe BB, runs a smaller pipe E, through which steam is passed in the direction

indicated by the arrow head. This steam pipe heats the liquor in BB, and this together with the fact that a certain amount of steam is continually escaping at the bottom through the perforations FF, cause a general movement of the hot liquor up through B, the colder coming in at the bottom opening CC, to take its place, thus keeping up more or less of a circulation. When the rising

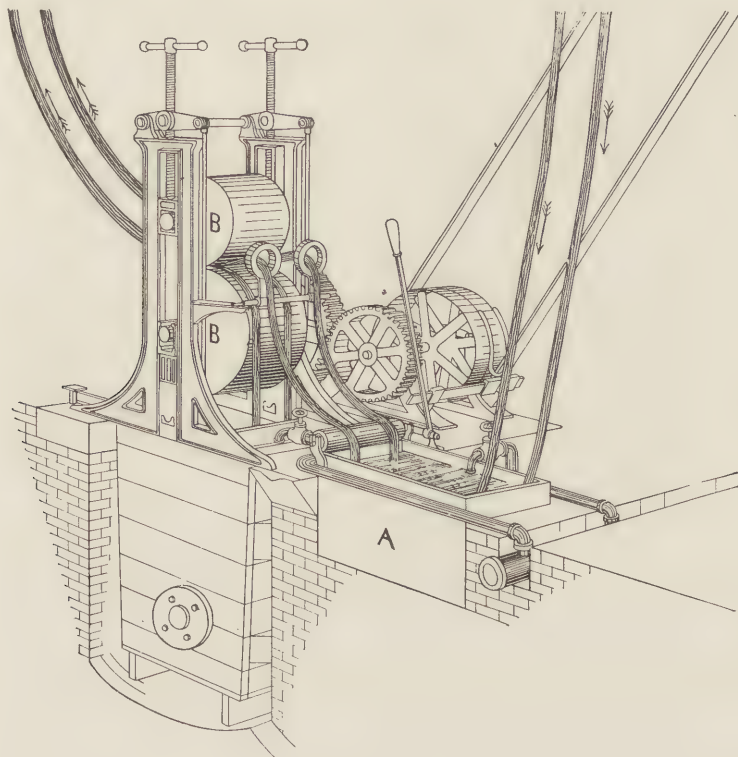


Fig. 31. Liming Machine.

liquor comes against the Baffle plate or bonnet P, it showers over the surface of the material which is contained in the kier, gradually leaches through it, passes through the false bottom, and is finally brought to the top again through BB.

The great loss of heat from this kier by radiation, and the large amount of steam necessary to keep up the circulation, led to the introduction of the so-called closed Low Pressure Kier, Figs.



34 and 35 serving as an example. In this form of kier the top may be closed tight and the boiling done under a slight pressure, say of 5 to 10 lbs., or a vent pipe is sometimes introduced in the top which allows the boiling to take place at atmospheric pressure. The circulation of the liquor in the kier is kept up in this way. Steam enters the injector B. through the pipe C, and the steam in passing up through the central pipe D, carries with it

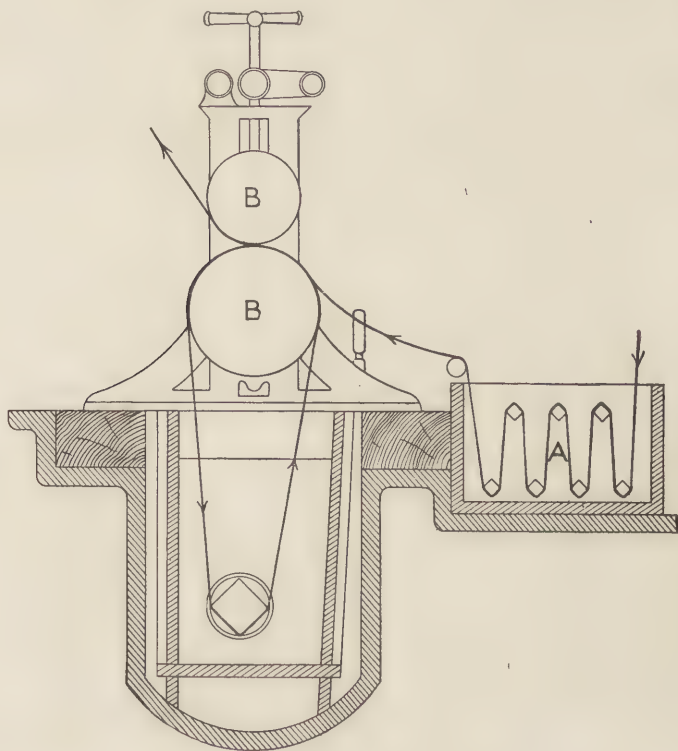


Fig. 31 A. Cross Section of Fig. 31.

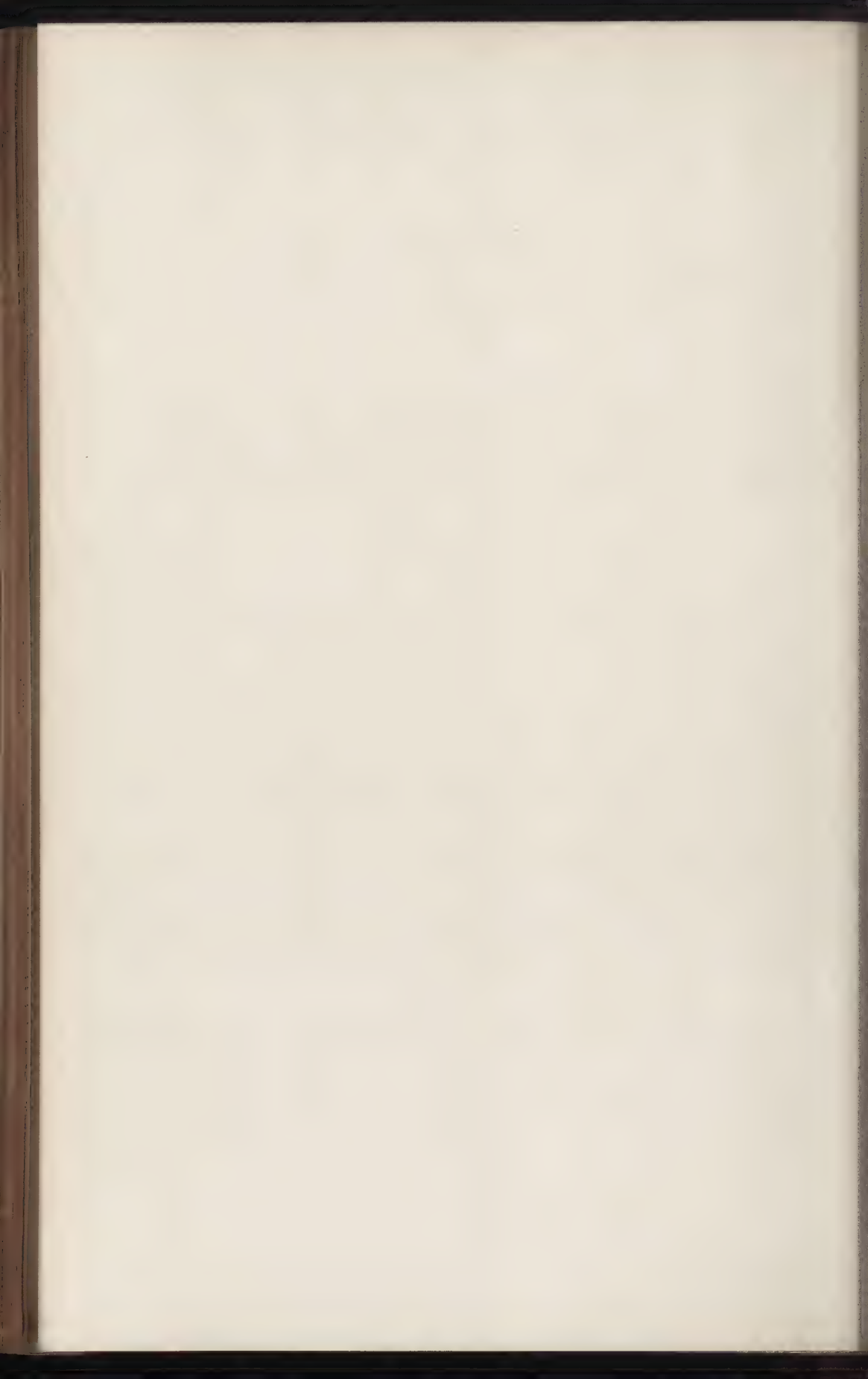
the liquor which is constantly flowing from the bottom of the kier into the injector through the pipe A. Through the valve E, the contents of the kier may be discharged after the boiling.

The gain in economy of this kier was slight, but nevertheless many of the older bleachers hold to this form, and it is not uncommon at the present time to find bleacheries using low pressure kiers of some type or other. Open kiers have the advantage of



**BLEACH HOUSE WASHING MACHINE, DRIVEN BY FRICTION PULLEY**

Textile Finishing Machinery Co.





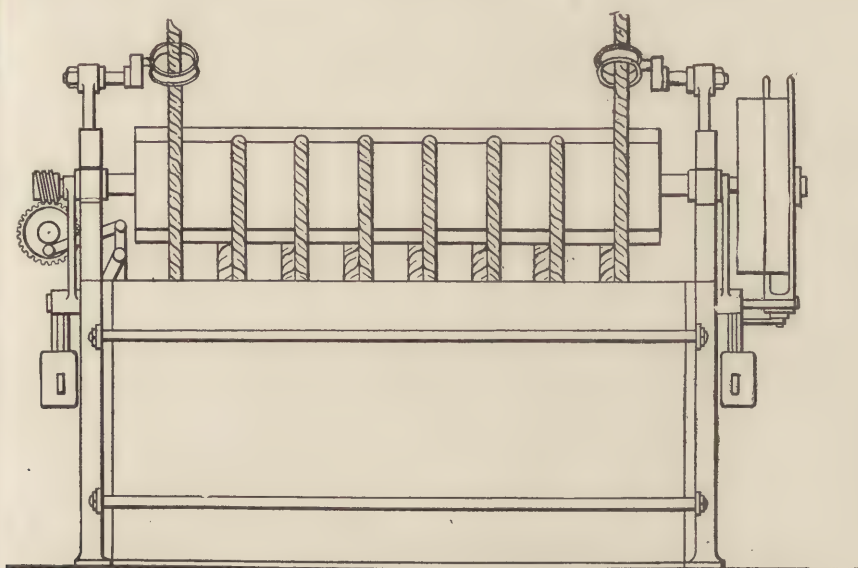


Fig. 32. Another Form of Liming Machine.

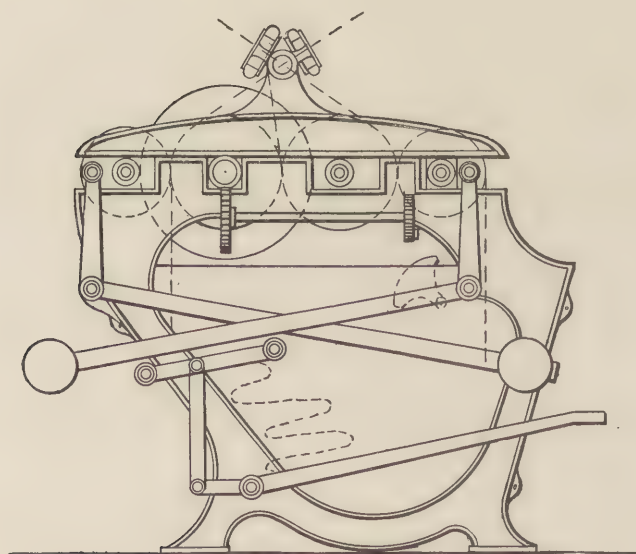


Fig. 32 A. End View of Fig. 32.

minimizing the risk of "kier tendering" which is the bane of a bleacher's life, but modern bleacheries particularly at print works equipped within recent years use pressure kiers almost without exception.

**Pressure Kiers** are commonly made of wrought or boiler iron, are cylindrical in form, and usually stand in an upright position.

They vary greatly in capacity, but a common size in a large bleachery is about 7 to 8 ft. in diameter and 10 ft. in height, hold-

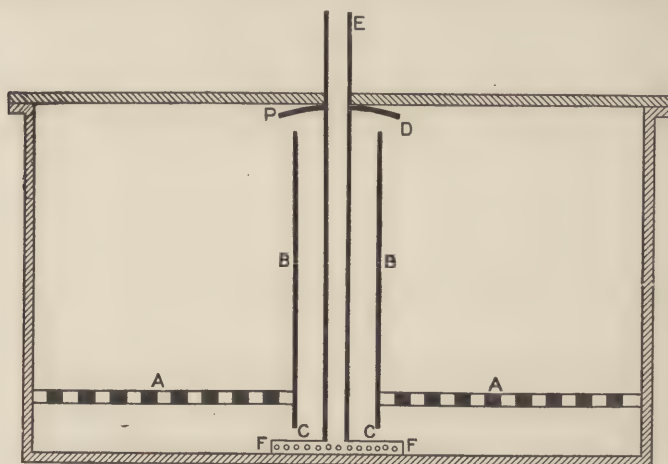


Fig. 33. Old Type of Open Kier.

ing as many as 700 to 1000 pieces of cloth. They are commonly used at a pressure of between 35 and 50 lbs., but are sometimes run at as low as 10 lbs. pressure. They should be able to safely stand a pressure of 70 lbs.

*Pressure kiers exist in two distinct types,*

(1). Those in which the circulation of the liquor is brought about by means of steam pressure; the liquor being forced from one kier to another, or into an auxiliary tank and then back into the kier.

The Barlow and Pendlebury kiers are examples of this class.

(2). Those in which the circulation of the liquor is kept up by means of steam injectors or pumps. To this class belong most of the modern kiers.

Barlow kiers always work in pairs, the construction and arrangement of which will be seen in Fig. 36.

In starting, both kiers are filled with cloth. Steam is blown through the kiers long enough to thoroughly clear them of air, and enough liquor then admitted through G to completely fill kier A. Kier A' is meanwhile filled with steam. By opening

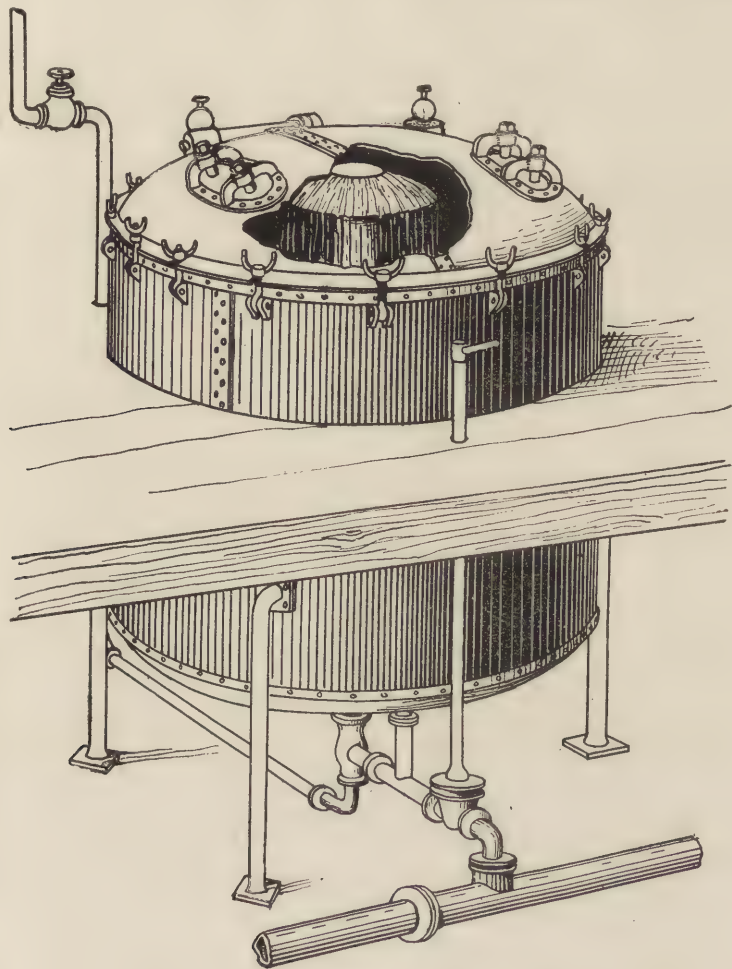


Fig. 34. Modern Low Pressure Kier.

the valve E and properly adjusting the 2 way valve V and V', steam is allowed to enter A under pressure through the perforated pipe C thus causing the liquor in the kier to boil. This boiling is continued for about 15 minutes, when by reversing the



2 way valves V and V' the steam pressure forces the liquor in A first through the goods, and then through the pipe D' and the perforated pipe C' into A'. After another 15 minutes' boiling the liquor is blown back into A. This alternating process is continued until the goods are sufficiently boiled, usually 5 to 7 hours, when the liquor is run off through H and the cloth cooled and washed.

Barlow Kiers could only be operated economically in large

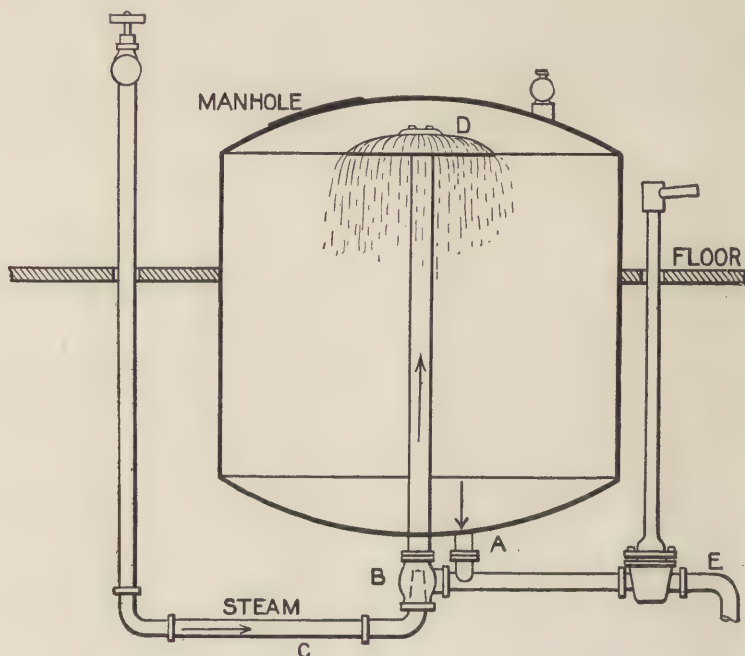


Fig. 35. Cross Section of Fig. 34.

bleacheries on account of the large amount of cloth required to fill two kiers. On this account Pendlebury invented his kier. See Fig. 37.

The Pendlebury System differs from the Barlow system in that the second kier is replaced by a much smaller one, which contains no cloth but acts only as a reservoir into which the liquor can be forced, and then after the proper period returned to the kier.

One advantage of this first type of kier is that the cloth is drained dry, after each period of circulation, and the returning liquor comes in contact with the hot and almost dry cloth, which when in this condition is more thoroughly permeated by the liquor.

On the other hand this system requires constant supervision and opening and closing of valves, while automatic appliances which require little or no attention are much more desirable.

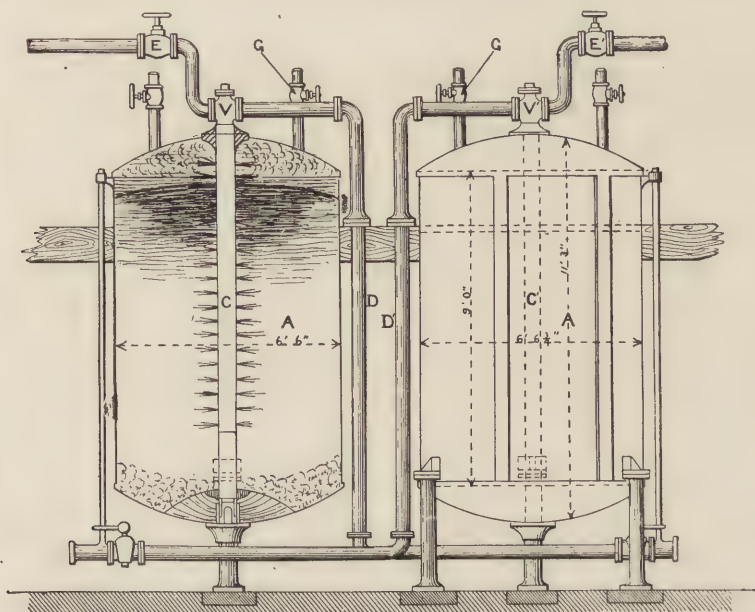


Fig. 36. Barlow Kiers.

For this reason the Barlow and Pendlebury kiers have been gradually going out of use, and one often finds at the present time bleacheries where all the kiers of this form have been replaced or made over into kiers of the second type.

The second type of kiers may be divided into two classes.

*First: Injector Kiers.*

*Second:* Those in which the circulation is kept up by means of pumps.

Injector kiers are so called because the bowking liquor is caused to circulate by means of a steam injector.

The action of the steam injector depends upon the fact that a current of live steam issuing through a tapering pipe or nozzle into another pipe containing a liquid, will, if the pipes are arranged properly, carry that liquid along with it. Thus in Fig. 38 steam escaping through A will carry along with it the liquid in B, and cause it to circulate through P in the direction indicated by the arrow heads.

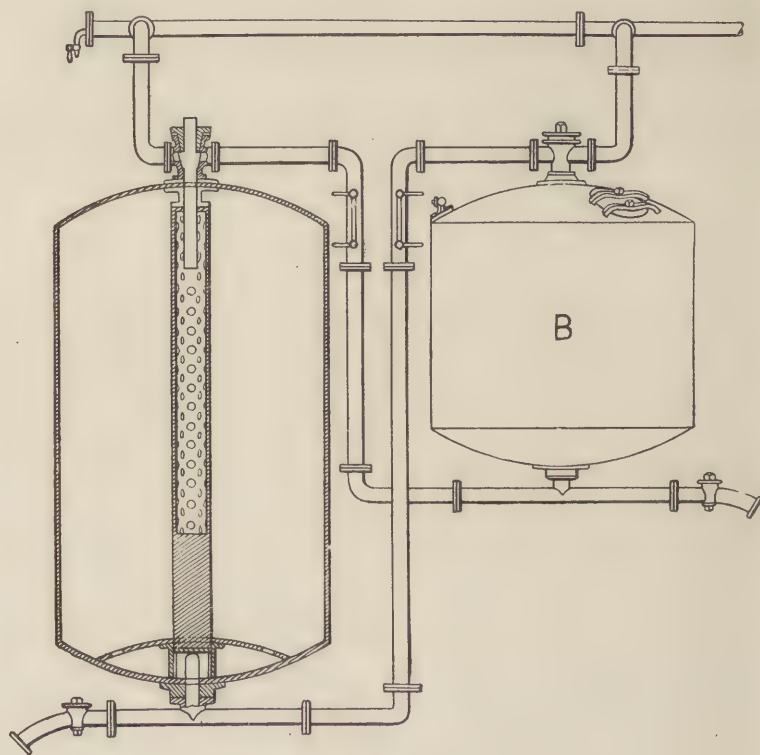


Fig. 37. Pendlebury Kier.

A common form of injector kier is illustrated in Fig. 39. The liquor in the kier runs into the pipe P, through the opening K, then into the steam injector J, and is carried up through the so-called vomit or puffer pipe V, and sprays itself at N, over the surface of the material in the kier. The steam enters the injector through the pipe S.



The puffer pipe is often located within the kier, with the injector just below, as in Fig. 34-35.

Fig. 40 represents Sir James Farmer's injector kier, which is distinguished by its indicator and automatic circulation governor.

The circulation is kept up by a special form of injector J, which is constructed in such a way as to use as little steam as is possible; this works in connection with a reducing valve R which facilitates the watching of the progress of the operations by the bleacher.

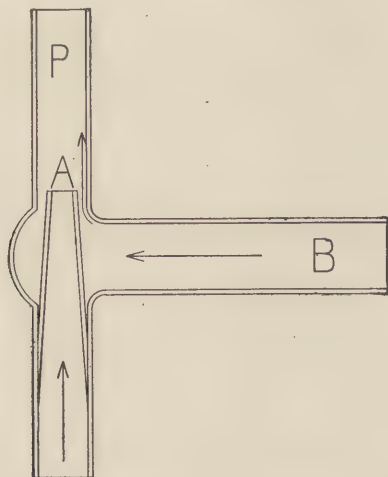


Fig. 38. Principle of the Injector.

The special governor and indicator shown at the top of the apparatus, however, is its special feature.

It is a well known fact that much difficulty is often experienced in obtaining uniform and regular circulation in an injector kier. The injector stops or gets caught, as they say, and the result is imperfect boiling and consequently imperfect bleaching. The conditions leading to this interruption of the circulation are as follows:

*First:* If the temperature rises higher than is desired for any reason, the steam must be turned off and necessarily the circulation immediately stops.

*Second:* If for any reason a higher temperature is desired more steam must be turned on and finally the bowking liquor

becomes so hot as to cease circulating and little but steam passes through the circulation pipe.

*Third:* There is a tendency for the circulation to stop or become irregular when there is not enough difference between the

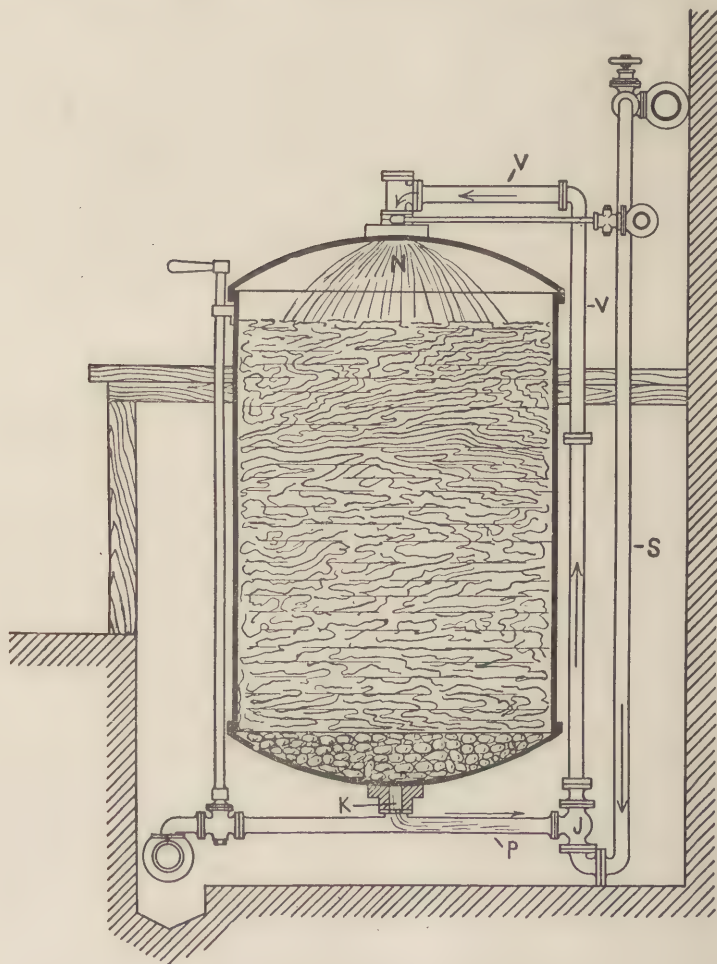


Fig. 39. Common Form of Injector Kier.

pressure of the steam entering the injector and the pressure of the steam in the kier.

In this kier these difficulties are overcome. The circulation seems to be very regular and the period of boiling is reduced to a minimum.

In brief, the working of the regulator is as follows :

At one end of the compound lever L.L.L. is a perforated bonnet B, and at the other end an air valve V. According to the force of the steam and liquor coming through the injector, the bonnet B works up and down. As long as the circulation is normal the air valve V remains closed, but should the pressure

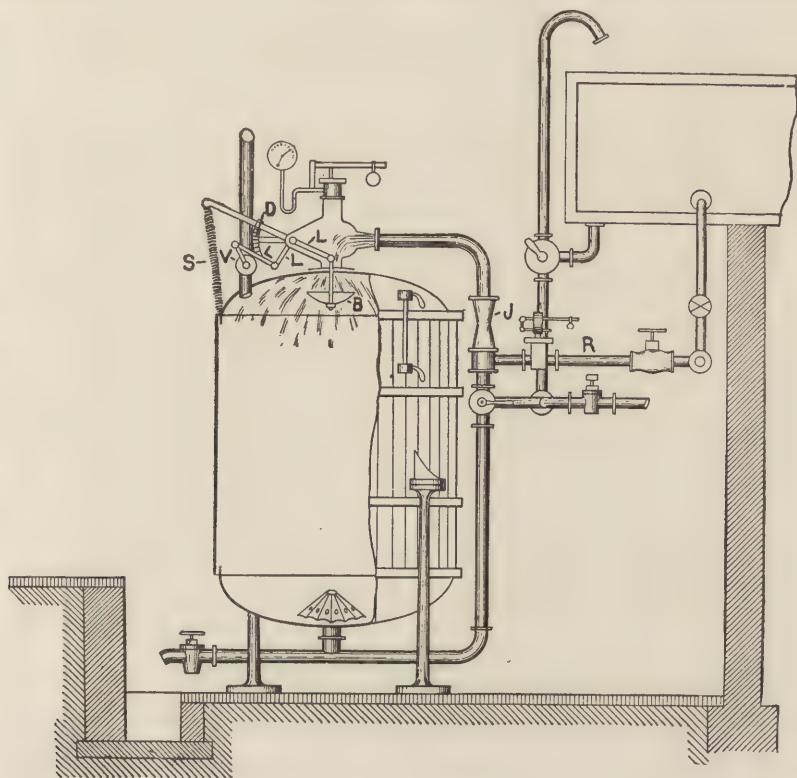


Fig. 40. Farmer's Kier.

become too great and the circulation stop, the tension of the spring S slightly raises the bonnet B, thus opening the air valve V, re-establishing the difference of pressure between the steam in the kier and that in the injector, and preventing the circulation from stopping for more than a moment. The bleacher controls the process by watching the movements of the lever on the circular dial D. In addition to the above, this kier may be said to possess the advantages of all other kiers of similar type.



Another kier which has been operated with considerable success is the Allen Kier, built by the W. M. Allen and Sons Co., Worcester, Mass., and illustrated in Fig. 41.

It is of the injector type but entirely does away with the

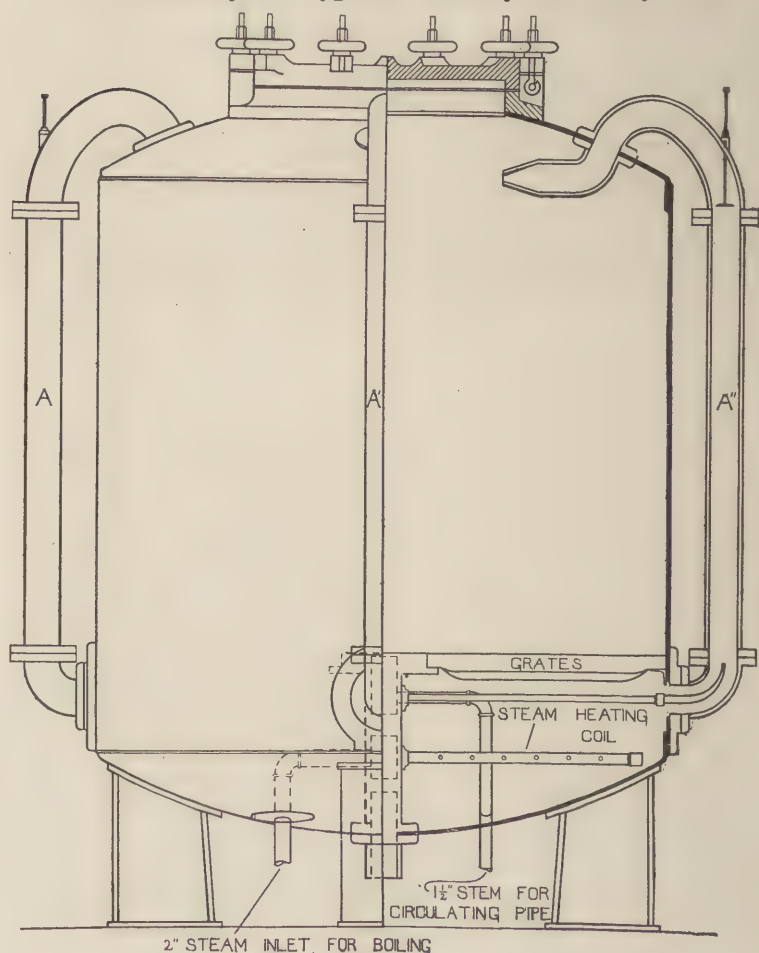


Fig. 41. Allen Kier.

central vomit pipe, having in its place four symmetrically located external pipes A, A', A'' and A''', which extend from the well at the bottom to the top, entering near the side, thus leaving the center of the top clear for a manhole. Each of the pipes is provided with an injector, represented in A'' at I, and after entering

the kier at the top flattens out into a fan-shaped nozzle which showers the liquor upon the surface of the goods. The circulation and boiling systems are wholly independent of each other, and

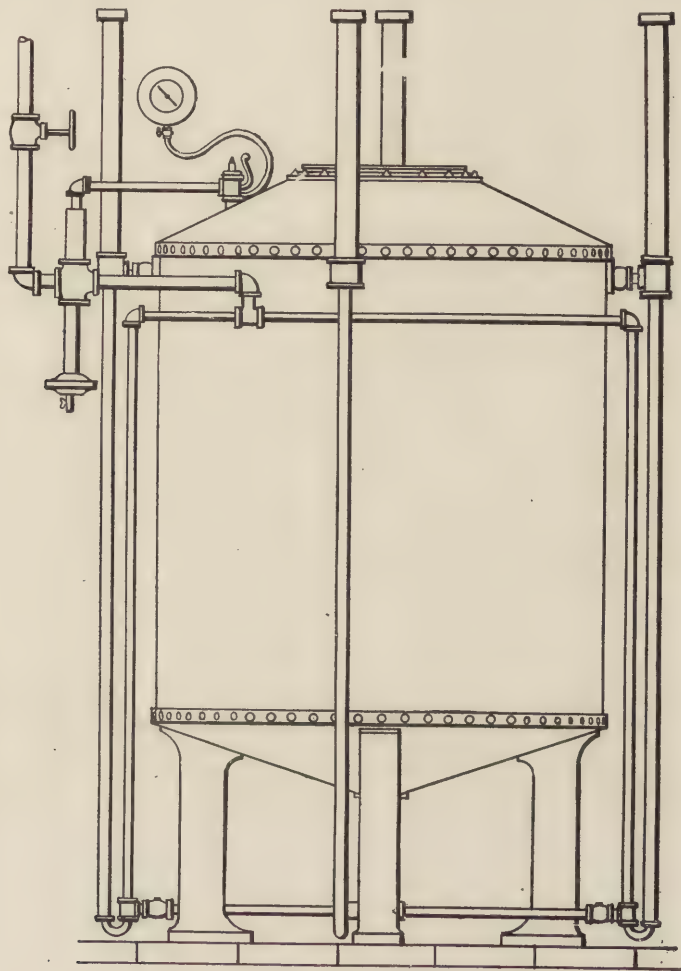


Fig. 42. Another Type of Outside Circulation Pressure Kier.  
Carpenter and Jefferson Kier.

one valve for each is all that is required. Each vomit pipe is provided with a telltale which indicates the condition of the circulation.

The Allen kier is economical in the amount of steam used, the circulation is rapid and strong and with proper management

gives excellent results. Care should be taken that all four of the circulating pipes work equally well, for if one should stop any length of time the material would become more or less dry on one side, a condition which might result in local tendering.

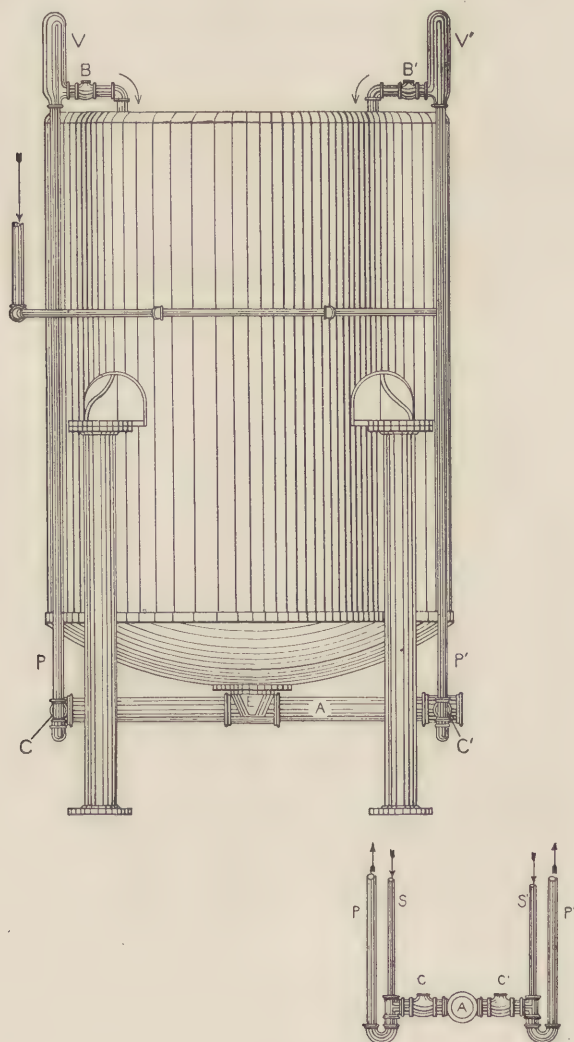


Fig. 43. Open Kier. Same as Fig. 42.

Another form of outside vomiting device worthy of mention is that recently introduced by Carpenter and Jefferson, contract-



ing engineers of Lowell, Mass. The circulation is not brought about by the injector principal purely, but by the aid of check valves and condensing pipes, which produce a partial vacuum. Fig. 42 gives the general arrangement of their device as applied to the pressure kier while Fig. 43 representing a low pressure kier will give an idea of its action. The liquor which has leached through the cloth in the kier runs into the pipe A at E. C and C' are two check valves which allow the liquor to pass through in the direction indicated by the arrow heads but will not allow

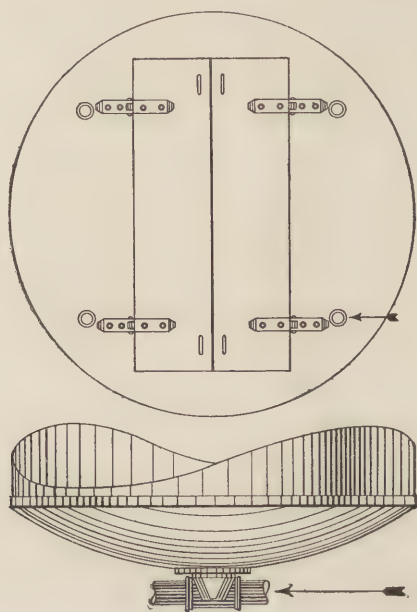


Fig. 43 A. Top and Bottom View of Fig. 43.

any to pass in the opposite direction. Steam is constantly being introduced through the pipe S and S', and as this can not go through the valves C and C' it passes up through P and P', carrying with it any liquor that may have passed through the check valves from the kier. When the steam reaches the chamber V the tendency is for it to condense on account of the large surface exposed to the air. This condensation causes a partial vacuum which aids materially in drawing the liquor up through P. B and B' are two more check valves which allow

liquor to pass in the direction indicated by the arrow heads, but not in the other, thus making a backward circulation impossible. These kiers are as yet in more or less of an experimental stage, and it is not possible, at present, to make a positive statement as to their value. A number of the large bleacheries are now giving them a trial, and they are said to be working well.

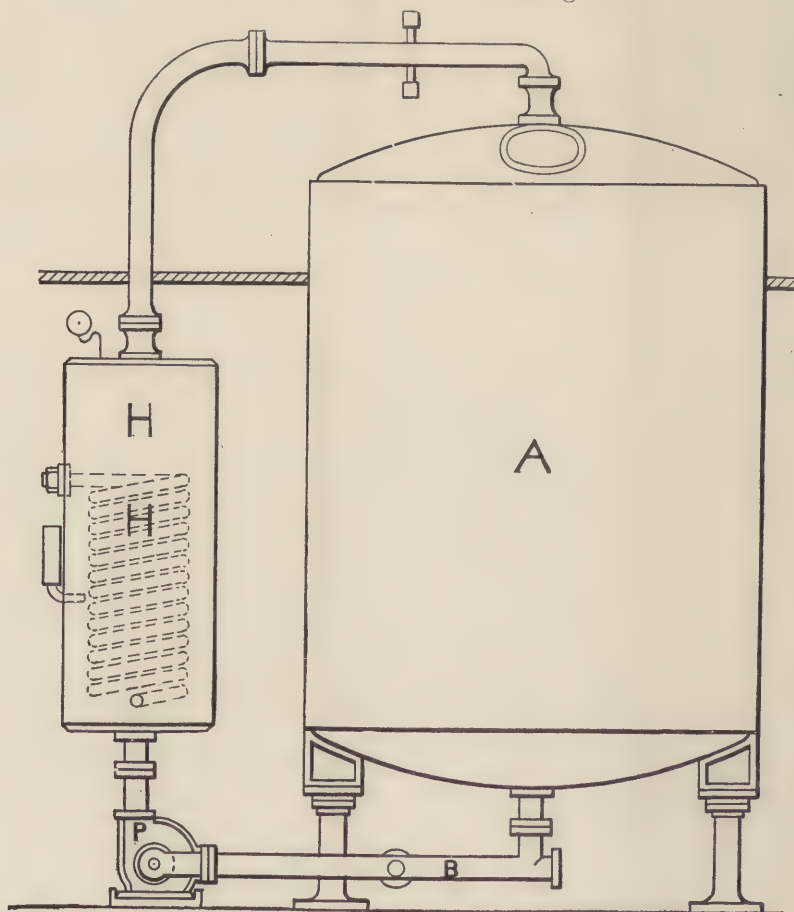


Fig. 44. Kier in Which Circulation is Brought About by Pumping.

There still remains to be mentioned the form of kier in which the circulation is brought about by pumping. A kier of this kind is well illustrated by Fig. 44. It consists of an ordinary kier A, with an opening at the center of the bottom through which

the liquor, after leaching through the cloth runs into the pipe B, and is forced by the pump P, through the heater H, and back into the kier at the middle of the top where it strikes a bonnet and is sprayed over the goods.

The capacity of the pump should be such that the whole body of the liquor is circulated every 20 to 30 minutes. The feature of this form of kier is that positive circulation is assured, and that the bowking liquor is not diluted by the large amount of steam that is constantly entering through an injector. This form of kier has met with increased favor during recent years.

The Mather Steamer Kier might well be described under this head as the circulation is brought about by a rotary pump, but as this kier is not used in connection with the lime boil, but for a special process, it will be described later. See No. 120.

When iron kiers are new there is more or less fear from rust, but after they have been in use some time the interior becomes covered with a hard coating of lime which prevents further oxidation. It is customary, particularly when the kiers are new to frequently apply a coating of whitewash to the inside. When open kiers are used it is absolutely necessary that the material being bleached should be held down below the surface of the liquor, for if cotton material in the presence of an alkali comes in contact with the air at a high temperature, tendering will take place. The amount of liquor necessary to fill a kier to the proper point for the boiling after the cloth has been introduced is not usually great, as each piece of cloth commonly carries approximately one gallon of the lime water with it as it passes into the kier.

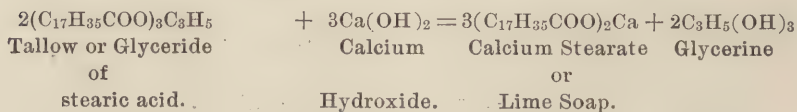
Great care must be taken in packing the goods into the kier, for a poor circulation is often the result of poor packing.

Another trouble which may result from both careless packing and poor circulation, might be termed the turning over of the goods in the kier. Under certain conditions too great a pressure beneath the goods as compared with that above is attained all at once, and if this inequality of pressure cannot be relieved through natural channels, a large quantity of steam will often rush up through the goods, disarranging and overturning them to such an extent as to disturb the process and seriously interfere with their removal from the kier.

**101. Chemistry of the Lime Boil.** As previously described (See 99 and 100), the lime boil consists in boiling the material in the presence of calcium hydroxide and water for a period of from five to twelve hours, depending chiefly upon the form of kier used and to some extent upon the fancy of the bleacher.

During the boiling the principal action seems to be the decomposition or saponification of the fatty and oily matter present, but there is, at the same time, a marked action upon the cotton wax and resinous matter and also the starchy substances introduced with the size.

Most fats and oils present being glycerides, the reaction may be represented by the following equation:



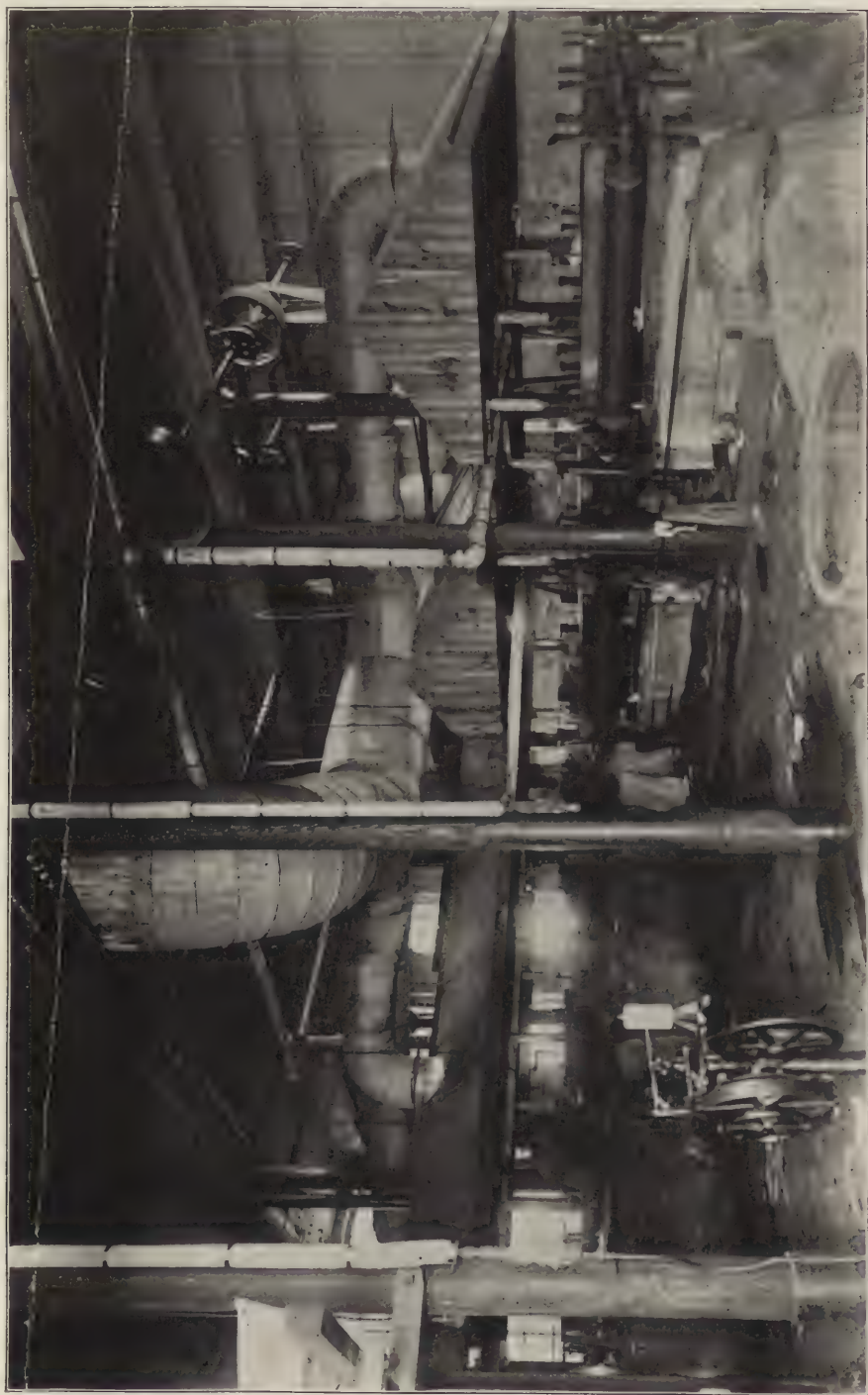
The above equation represents the action of lime on the glyceride of stearic acid, commonly called tallow, but the reaction would take place with any other glyceride in a similar manner. Thus no matter what the fats present may be, at the end of the lime boil they will have been converted into the lime soaps or salts of the fatty acids they contain, and glycerine. (See Organic Chemistry.)

Lime soaps are as insoluble in water as the fats from which they are derived and for this reason they are not removed in the washing that follows, but are still present on the cloth when it passes to the brown sour.

The question is often raised: why not omit the lime boil and saponify directly with caustic soda or soda ash (See No. 105) thus producing a soluble soda soap that can be immediately washed from the cloth? This is done with much success in the Mather kier process (See No. 120) but experience and experiment have shown that calcium hydroxide at a boiling temperature and under pressure attacks the fatty matter (but more particularly the cotton wax and resinous matter present) more energetically even than caustic soda. At the same time lime is very cheap.

M. Albert Scheurer who has made a thorough investigation





20 H. P. INDUCTION MOTOR DRIVING JIGGS  
Lonsdale Bleachery



of the subject says, "It has been shown that at  $120^{\circ}\text{C}$ , the natural fats of cotton are saponified in less than two hours by the lime boil, and tallow in four hours. This is remarkable since caustic soda and rosin at the same temperature require eight hours." In

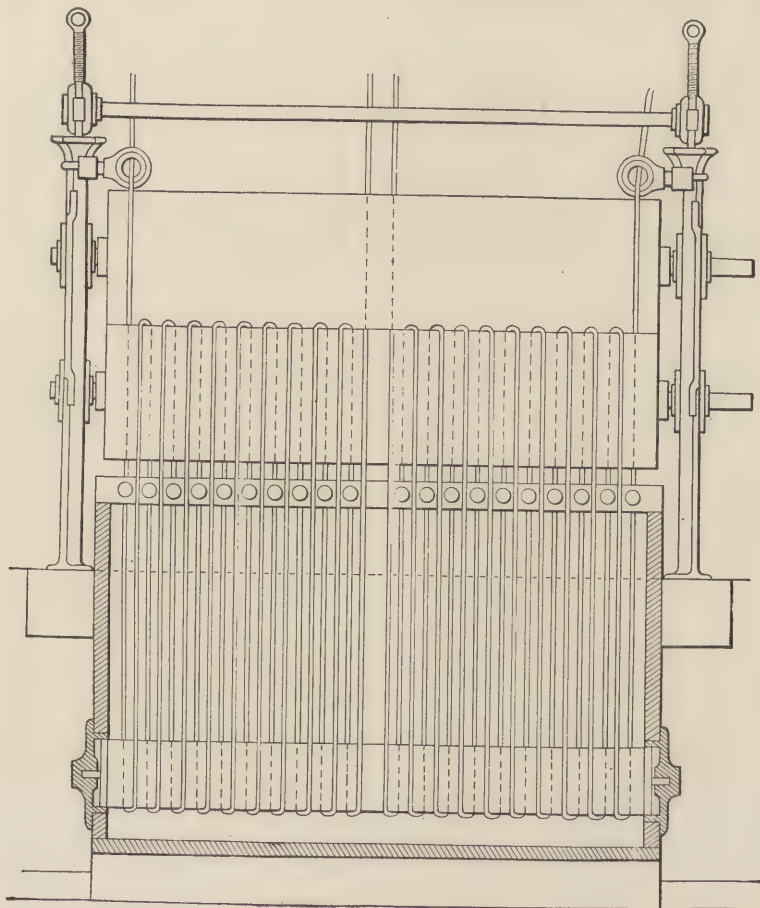


Fig. 45. Washing Machine.

addition many bleachers claim that goods given a lime boil have less tendency to become yellow on storing.

The exact cause of tendering during the lime boil, particularly in high pressure kiers has been a much discussed point. Experimental investigation shows that lime at a high temperature in the presence of the oxygen of the air will convert cellulose into

oxycellulose, a substance having but little structural strength. Kier tendering is undoubtedly due to the existence of these conditions in the kier, commonly brought about by an insufficient amount of liquor.

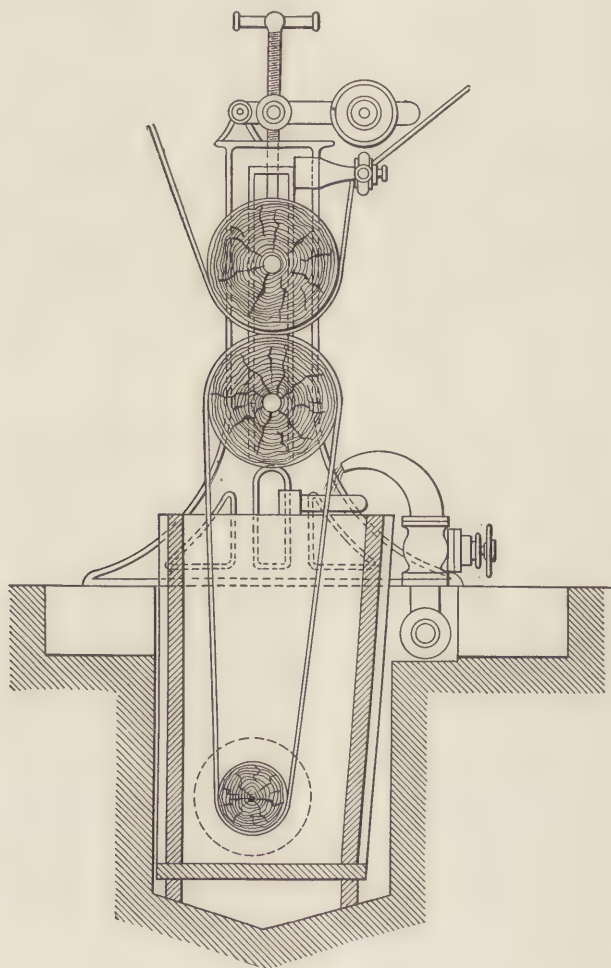


Fig. 45 A. Cross Section of Fig. 45.

#### 102. Wash Following the Lime Boil and its Object.

When the lime boil is finished the liquor is run off, and it is well to immediately give the goods a preliminary wash with cold water in the kier, particularly if found necessary to leave the material



some time before running it through the washing machine. This cools off the goods before they come in contact with the air, and prevents them from drying while saturated with lime.

As soon as possible, the goods are run directly from the kier through a washing machine. See Figs. 45 and 45A. The object of this wash is to remove the excess of lime, and any soluble substances that may have been formed during the lime boil.

For further discussion of the washing of Textiles see also 112.

**103. The Brown Sour and its Chemistry.** The acid treatment following the lime boil is commonly known as the Brown sour, also as the grey sour, and sometimes as the lime sour. It consists in passing the cloth through a dilute acid solution, allowing it to stand for a short period dampened with this acid solution, and then washing with water.

The object is to remove all calcium (or lime) that may be present, as well as any other metals, such as iron, that may have been precipitated upon the cloth in some insoluble form during the lime boil.

The acids commonly used for souring cotton material during bleaching processes are sulphuric (oil of vitriol), and hydrochloric (muriatic) acids. For the brown sour it is not advisable to use sulphuric acid alone, since the calcium sulphate formed would be very difficultly soluble in water, but instead either hydrochloric acid, or a mixture of hydrochloric and sulphuric acids, thus forming calcium chloride which is extremely soluble in water and therefore easily removed during the wash which follows.

Experience has shown that a mixture of hydrochloric and sulphuric acids made up as follows works very well: In the mixing tank introduce 75 gallons of water then two carboys of sulphuric acid followed by two carboys of hydrochloric acid, then enough water to bring the Sp.G. to 10° Tw. This is then run into the souring machine. The water introduced by the cloth, as it enters the souring machine dilutes the acid considerable but enough water should be added along with the 10° acid to constantly keep it at a strength of about 3° Tw.

The souring machine should be of such construction that the goods pass through slow enough to insure that every portion of

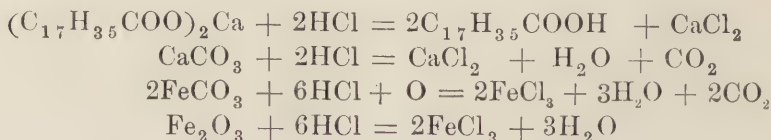
the material is acted upon by the acid. The same form of machines as are used for liming, see Fig. 31 and 32, are also commonly used for this purpose.

After leaving the souring machine the goods are commonly allowed to remain piled up in a bin for several hours or even over night. In the latter case it is advisable to sprinkle or wet down the cloth with water to prevent it from becoming tendered, see No. 21. Where time is an object the strength of the acid may be increased, say to  $3\frac{1}{2}^{\circ}$  Tw. but when possible it is better to lengthen the time of souring and diminish the strength of the acid to  $2^{\circ}$  or even  $1\frac{1}{2}$  Tw. Some bleachers recommend using acid as weak as  $\frac{1}{2}^{\circ}$  Tw. and heating it to about  $90^{\circ}$  C. for twenty minutes to one half hour.

The chemistry of the Brown sour is as follows:

There is present upon the cloth as it comes from the lime boil the insoluble calcium soaps [as for example calcium stearate  $(C_{17}H_{35}COO)_2Ca$ ,] a certain amount of calcium carbonate  $CaCO_3$  formed by the action of the carbon dioxide of the air upon the lime, and sometimes small amounts of the insoluble soaps of metals other than calcium and the oxide and carbonate of iron.

The following equations represent the reactions taking place if hydrochloric acid is present in the souring bath:



The chlorides formed being readily soluble in water are completely removed in the washing which follows. The fatty acids liberated (as for example Stearic Acid  $C_{17}H_{35}COOH$ ) are all insoluble in water and consequently remain on the cloth. These however are readily removed in the lye boils.

The so-called lime stains which sometimes appear upon the bleached cloth and cause trouble in dyeing and printing are most frequently due to insufficient souring or the use of too little hydrochloric acid.

After the brown sour the cloth is passed through a washing

machine and is ready for the lye boils. If any free acid remains in the cloth there is danger of the formation of iron stains when it is run into the kier. To prevent this it is advisable to run the cloth through soda ash solution then through squeeze rolls before entering the kier.

**104. Lye Boils.** Originally there were two and sometimes three so-called lye boils given during the madder bleach.

The first was always a short one and had for its object the thorough wetting out and softening of the cloth, and the complete neutralization of any acid that might have remained on the cloth after the brown sour. Soda ash alone was used in this.

In the second, which was the essential one of the three, the boiling lasted from 12 to 24 hours in the case of open kiers and from 6 to 12 hours in the case of pressure kiers, and there were used in addition to soda ash, rosin soap and a small amount of caustic soda.

The third was a short one, with soda ash alone, and was to insure the complete removal of any of the rosin soap that might remain on the cloth.

Of late years the tendency has been to shorten the process as much as possible, the first boil being entirely done away with when the cloth is passed through soda ash solution and squeeze rolls before entering the kier, and the second and third combined as one which we will designate as the rosin soap boil.

**Rosin Soap Boil.** The alkalies available for this boil are sodium carbonate (soda ash), and sodium hydroxide (caustic soda), the corresponding potassium compounds being ruled out on account of expense.

The other boiling agent used is rosin or rosin soap which may conveniently be made by boiling

100 lbs. of Rosin with

10 gallons of Caustic Soda solution 60° Tw.

and sufficient water to make a perfectly homogeneous mass.

The main object of the Rosin Soap Lye Boil is to convert all fatty acids present into their soluble sodium salts or soaps, and at the same time remove other fatty and waxy matters, and most of the resinous brown coloring matter still remaining in the cloth.

Caustic Soda attacks these substances very energetically and is particularly useful in removing any natural fatty compounds which may have escaped decomposition during the lime boil. Theoretically it is an excellent reagent for this purpose but great care must be taken in its use or tendering will result.

Soda ash accomplishes the same purpose as caustic soda but is much slower in its action. It is by far the safer and is the standard alkali for this purpose. In order to shorten the time however without running too great risk, bleachers often use a mixture of soda ash and caustic soda, a good proportion being 85 parts of the former to 15 of the latter.

The same form of kier (See 100), may be used for the lye boils as are used for the lime boils, although it is customary to have separate ones for each.

The length of the boil necessarily varies with the form of kier, the material being bleached, and the fancy of the bleacher, but for ordinary print cloth it usually lasts from 6 to 12 hours.

For 500 pieces of print cloth it is customary to use approximately the following chemicals:

150 lbs. of Soda Ash, and

Rosin soap corresponding to 13 lbs. of Rosin.

In place of the above amount of Soda Ash, a mixture of

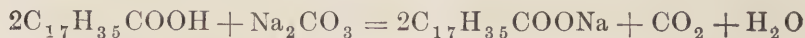
20 lbs. of Caustic Soda, and

120 lbs. of Soda Ash

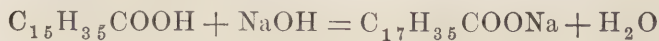
may be used.

**105. Chemistry of the Lye Boils.** The most important chemical reaction taking place during the Lye boil is the conversion of the free fatty acids present into their corresponding sodium salts or soaps which are soluble in water. Illustrating with stearic acid, we would have the following reactions taking place

With Soda Ash:



With Caustic Soda:



The Rosin Soap boil has always been a special feature of the



madder bleach, for it was found that in some way, not thoroughly understood, this agent removed, far better than soda ash alone, certain impurities which if allowed to remain, would attract certain coloring matters during subsequent dyeing and printing processes and thus detract from the purity of the white grounds. The action of the rosin soap is apparently of a mechanical emulsive nature rather than chemical. Other soaps might be used for this purpose, but as yet none have been found that work as well, or are as cheap as rosin soap.

**106. Wash Following the Lye Boil and its Object.** The wash following the lye boil is carried out in the ordinary washing machine Fig. 30 and if the third lye boil mentioned in 104 has been omitted, should be thorough in order to completely remove any rosin soap, which might stain the cloth if allowed to remain.

If the lye boil has been properly carried out, all the fatty matter still remaining will be present in a form perfectly soluble in water, and consequently easily removed at this time, and after leaving the washing machine, were it not for a small amount of natural coloring matter, the cloth should be nearly free from impurities.

**107. Chemicking or Bleaching Proper.** The chemicking or bleaching proper is given at this stage of the process.

It has for its object the complete removal or decolorization of the small amount of coloring matter remaining.

This is accomplished by passing the cloth through a moderately dilute bleaching powder solution (1° to 2° Tw.) allowing it to remain exposed to the air in a pile, while still damp with the bleaching powder solution, and then after a hasty wash passing it through a dilute acid solution (white sour), and thoroughly washing.

The bleaching powder solution may be applied to the cloth by various arrangements but all consist essentially of a cistern for saturating the cloth and squeeze rolls for removing the excess. The same form of machine as is used for souring will do, only in this case it is well to replace the wooden cistern with one of cement.

The bleaching powder is best dissolved in a special apparatus, as it goes into solution with some difficulty, and undissolved

lumps coming in contact with, and attaching themselves to the cloth may result in the formation of oxy cellulose. A simple form of apparatus for this purpose is represented in Fig. 46. It consists of a perforated, wrought iron, lead-lined drum, into which the bleaching powder is put. This drum is revolved in a rectangular lead-lined iron tank through which water is run. The bleaching powder solution is drawn off at a tap located far enough from the bottom to prevent the removal of sediment.

Numerous other forms of apparatus have been devised for this purpose, but need not be described here.

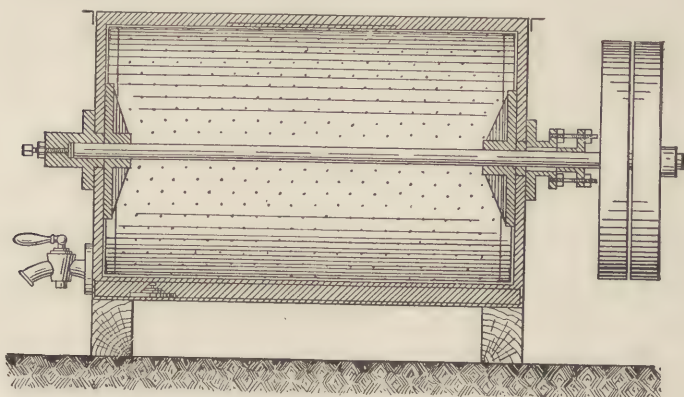


Fig. 46. Apparatus for Dissolving Bleaching Powder.

The solution of bleaching powder in the stock reservoir should stand at about  $3^{\circ}$  Tw. and the water introduced with the cloth will dilute this to about the proper strength. If not, water is introduced along with the stock solution as it passes into the chemicking machine. The cloth is passed through this solution, then through squeeze rolls and allowed to stand in a pile 1 or 2 hours. The time of this exposure varies with different bleachers. Some even allow the cloth to remain in this condition over night. This however is a dangerous practice, unless the bleaching powder solution is extremely dilute, owing to the danger of formation of oxy cellulose. For bleaching solutions of from  $1^{\circ}$  to  $2^{\circ}$  we should place the limit of exposure for the best results at 5 to 6 hours. It is also well to remember that the solution at a temperature of  $75^{\circ}$  to  $85^{\circ}$  F in the summer will act much

quicker than that of from 50° to 65° F, or colder, in the winter.

**108. Wash After Chemicking and its Object.** Before entering the white sour the goods are given a hasty wash, to remove any excess of bleaching powder. If this were not done, the amount of chlorine liberated during the souring would be so great as to be injurious to the workmen, even if it did not drive them all out of the bleach house.

**109. White Sour.** The white sour is carried out in a similar manner to the brown sour (See No. 103). It consists in passing the goods through a 2° to 2½° Tw. sulphuric acid solution, then through squeeze rolls and into the final washer.

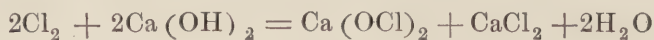
Its object is two-fold. First to decompose any bleaching powder that may remain, thus liberating the chlorine and preventing its subsequent action upon the cloth; and secondly to aid in the removal of all calcium compounds, particularly the carbonate, which is formed during the exposure with bleaching powder to the air.

A very energetic bleaching action also goes on during the white sour, owing to the rapid liberation of chlorine, and the cloth is left in a very white and bright condition.

As in the brown sour, it would, from a theoretical point of view, be better to use hydrochloric acid, but on account of the cheapness of sulphuric acid, and the fact that commercial hydrochloric acid sometimes contains enough iron to detract from the whiteness of the goods, the former is used.

**110. Bleaching Powder.** Chlorine and certain of its compounds are as yet the cheapest and, considering everything, the best bleaching agents for cotton, and the compound depended upon almost entirely for the liberation of these is Bleaching Powder.

When chlorine is allowed to act upon Calcium Hydroxide (water slaked lime), reaction takes place according to the following equation:

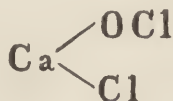


Bleaching Powder.

and bleaching powder results.

In the above equation bleaching powder is written as a mix-

ture of Calcium Hypochlorite,  $\text{Ca}(\text{OCl})_2$ , and Calcium Chloride  $\text{CaCl}_2$ , in molecular proportions. This could also be written as two molecules of an oxychloride of calcium  $2\text{CaOCl}_2$ , which would have the following structural formula:



There has been much discussion as to which was correct, but at the present time the opinion of most chemists is that bleaching powder, in the dry form, is a definite compound of the formula  $\text{CaOCl}_2$  which when dissolved in water dissociates or breaks up the same as would the mixture  $\text{Ca}(\text{OCl})_2 + \text{CaCl}_2$ .

Evidence very strongly in favor of this theory, which anyone can notice, is this. Calcium chloride  $\text{CaCl}_2$  is one of the most deliquescent compounds we have, while dry bleaching powder does not seem to be at all deliquescent. This latter fact would not seem possible if dry bleaching powder was made up of a little less than  $\frac{1}{2}$  calcium chloride.

Commercial Bleaching Powder may practically be considered as a mixture of calcium hypochlorite and calcium chloride in a somewhat variable proportion, with some calcium hydroxide and if the sample is old, and has been exposed to the air, some calcium carbonate.

As will be understood later (See 111,) it is only the Cl of the hypochlorite that is available for bleaching purposes and the value of any bleaching powder depends upon the amount of this present.

**111. Theory and Chemistry of Bleaching with Chlorine.** It is now believed by all chemists, that oxygen just liberated, (that is, when in the atomic condition, or nascent state), is the most powerful bleaching agent we have.

For hundreds of years it has been known that textile fabrics laid upon the grass exposed to the sun and air became thoroughly bleached and that the same material exposed to the sun and air but away from the grass, bleached much slower. This fact is easily explained when it is known that all vegetation is constantly

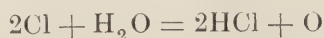


taking up carbon dioxide, retaining the carbon, which contributes to its growth, and giving up the oxygen. It is the oxygen given up from the grass that so actively aids in bleaching.

It is also known that many peroxides as those of hydrogen and sodium which readily liberate nascent or atomic oxygen are excellent bleaching agents.

Furthermore if a piece of perfectly dry cotton cloth is put into perfectly dry chlorine gas, there seems to be little if any bleaching action, but if the same piece of cloth be slightly moistened with water, and returned to the same chlorine it is rapidly bleached.

These and other facts lead to the belief that even when chlorine is used, the real bleaching action is due to the liberation of atomic or nascent oxygen, by the action of chlorine on water, thus:

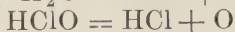
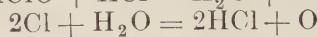
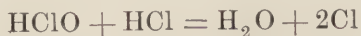
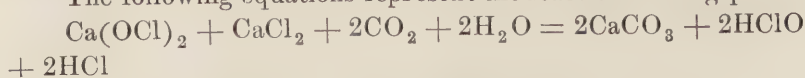


Calcium Hypochlorite  $\text{Ca}(\text{OCl})_2$  already spoken of as containing the available chlorine for bleaching powder, is a very unstable compound being readily decomposed by acids, even by carbonic acid gas, with the liberation of hypochlorous acid  $\text{HClO}$  which readily decomposes liberating hydrochloric acid and nascent oxygen as follows:

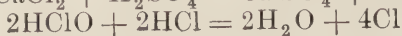
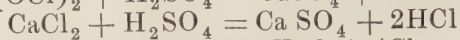
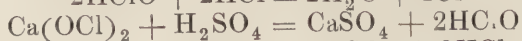
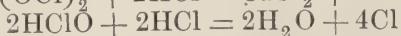
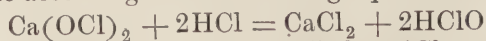


During the bleaching process dependence is mainly placed upon the slow decomposition brought about by the action of the carbon dioxide of the air upon the bleaching powder while the cloth is exposed dampened with a solution of the latter.

The following equations represent the reactions taking place:



Hydrochloric and Sulphuric Acid liberate Hypochlorous acid and Chlorine according to the following equations:

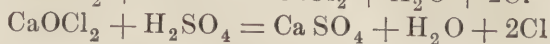
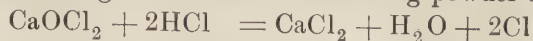


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Or considering the formula of bleaching powder as  $\text{Ca O Cl}_2$



The above equations represent the principal reactions taking place during the bleaching but in general it may be said that there is a cycle of reactions going on, in which the products of one reaction react with those of another, resulting in the slow but more or less uniform liberation of nascent oxygen; this nascent oxygen destroying or decolorizing the coloring matter that is present in the cloth.

#### 112. Final Wash and General Discussion of Washing.

Too much stress cannot be laid on the importance of careful and thorough washing of the material at the different stages of the bleaching process, and particularly after it has been completed, for in many cases deterioration and tendering of the cloth might be traced to insufficient washing rather than too strong liquors.

For satisfactory results it is imperative that all acid and bleaching powder should be removed from the cloth at the proper time, and it should also be remembered that heat is many times generated by the action of one chemical upon another, which in some cases is enough to cause tendering, unless it is overcome by immediately passing the cloth into an excess of water.

The commonest forms of washing machines are illustrated by Figs. 29-30-45-45A. They consist of large cisterns through which water can be passed with varying rapidity, and some means of passing the cloth through these, so that every portion will come in with a large volume of water.

The machines are commonly constructed with two heavy squeeze rolls above the cistern which vary in diameter. The lower roll is commonly the larger, being from 20 to 24 inches in diameter, while the upper is from 12 to 18 inches. There should be enough pressure between them, to draw in the wet cloth without slipping. The nip of the rolls is sometimes increased by covering them with rope.

The speed at which the cloth is passed through the washing machine depends on the nature of the material, the construction of the machine, and the number of times the cloth passes through the squeeze rolls. For an ordinary machine with print cloth the

200-250 ft. per min.  
100  
100-150 ft. per min.  
100-150 ft. per min.

rate is from 3 to 5 miles per hour. With certain tension machines this may be increased somewhat, but with very heavy material the speed is sometimes reduced to as low as 1 mile per hour. At any event the washing should always be thorough enough to remove

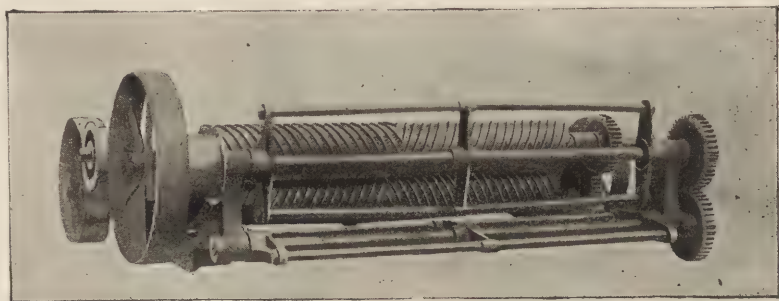


Fig. 47. Cylindrical Scutcher.

the last traces of acid or the material will become tendered when dried.

**113. Finishing.** After the final wash the cloth is hydro extracted or passed between the squeeze rolls and then brought again to the full width. It is sometimes opened out by hand, but

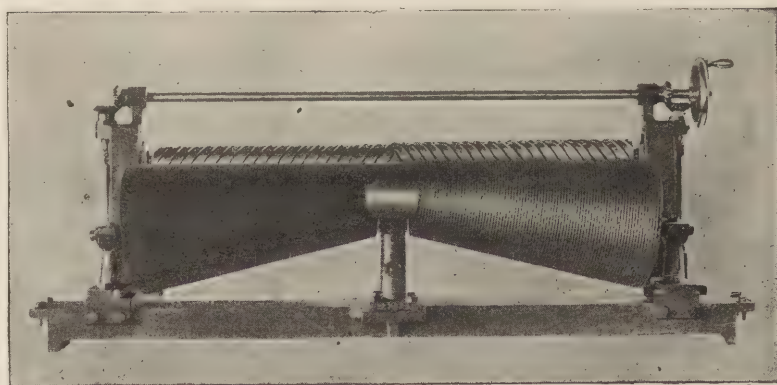


Fig. 48. Conical Scutcher.

a machine called a scutcher is more commonly used for this purpose. Scutchers vary in construction and working detail but all involve the principle of producing a stretching of the cloth from the center toward the edge by passing it over spirally grooved or



fluted rolls or diagonally grooved surfaces. Fig. 47 represents a plain cylindrical scutcher, Fig. 48 one of conical construction, Fig. 49 a reel scutcher, while Fig. 50 represents a self regulating one recently introduced by Wm. Mycock & Co. of Manchester, Eng., which is said to be giving great satisfaction.

If the cloth is to be printed it is simply dried by passing over drying cans, see Fig. 51, but if it is to be finished white it is passed through a starch mangle and through other finishing machines as calenders, beatlers, etc. The finishing of cotton cloth being a subject by itself will not be further considered here.

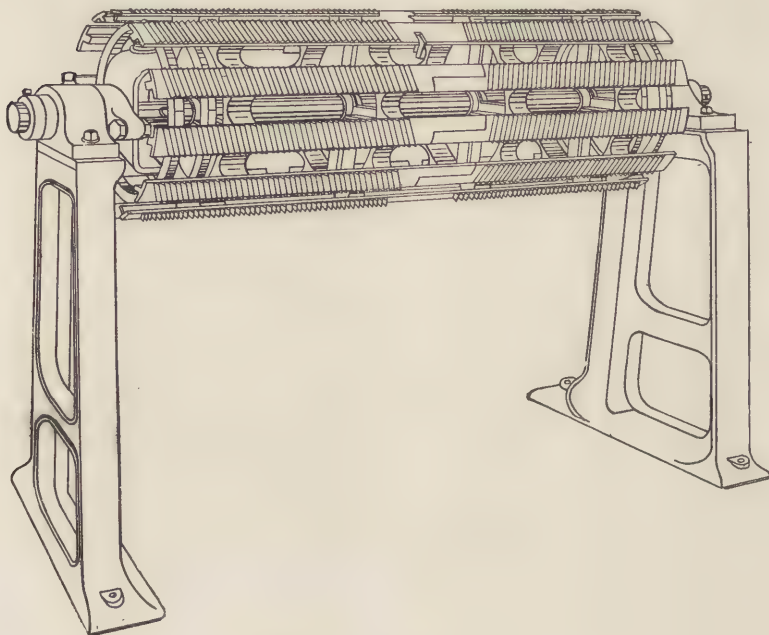


Fig. 49. Reel Scutcher.

**114. Turkey Red Bleach.** In the case of cloth that is to be dyed a full shade of Turkey or alizarine red, it is not necessary to give a complete madder bleach, for there is no white ground to be preserved, and many hold the opinion that previous treatment with bleaching powder detracts from the production of the most brilliant reds. This may be due to the formation of oxy-cellulose which prevents the proper fixation of the mordant. The treat-



ment for the so-called Turkey Red bleach differs from the madder bleach in that the lime boil, brown sour, and treatment with bleaching powder are omitted. The slight yellow color left on the cloth after this bleach tends to increase the fiery character of the shade produced.

**115. Market Bleach.** This term is sometimes applied to the bleach-given cloth that is sold in the white. It is an indefinite term, but in general consists of a bleach similar but not as

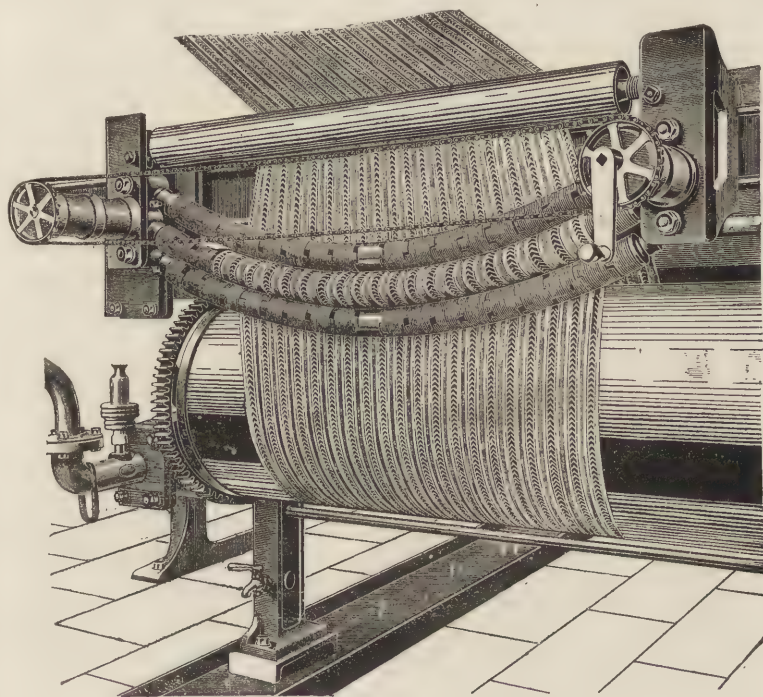


Fig. 50. Self Regulating Expander.

thorough as the madder bleach. Any remaining yellow tint is neutralized by blueing. The cloth is commonly starched and often slightly weighted and calendered.

**116. Rapid Bleach for Cloth that is to be Dyed Dark Shades.** Where cotton cloth is to be dyed a solid dark shade, it is only necessary to give it sufficient preliminary treatment to remove the cotton, wax, grease and dirt. It is commonly washed, boiled several hours with soda ash, given a rapid treatment with bleaching

powder and a sour. Sometimes the bleaching powder treatment is omitted entirely.

**117. Bleaching of Cotton Yarn. (General Consideration.)**

When cotton yarn is to be dyed black or dark colors, it matters little whether it is previously bleached or not. If bleach-

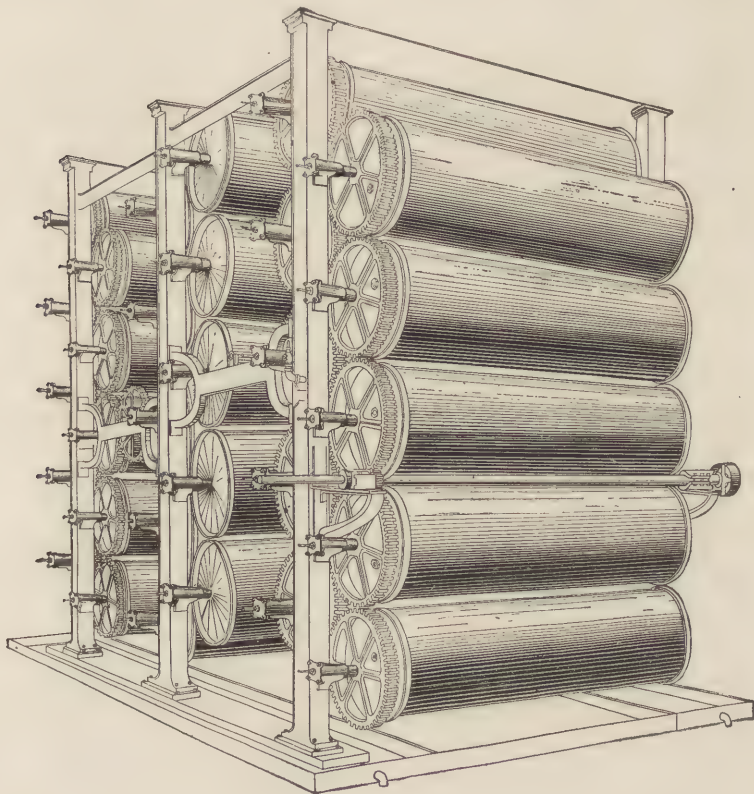
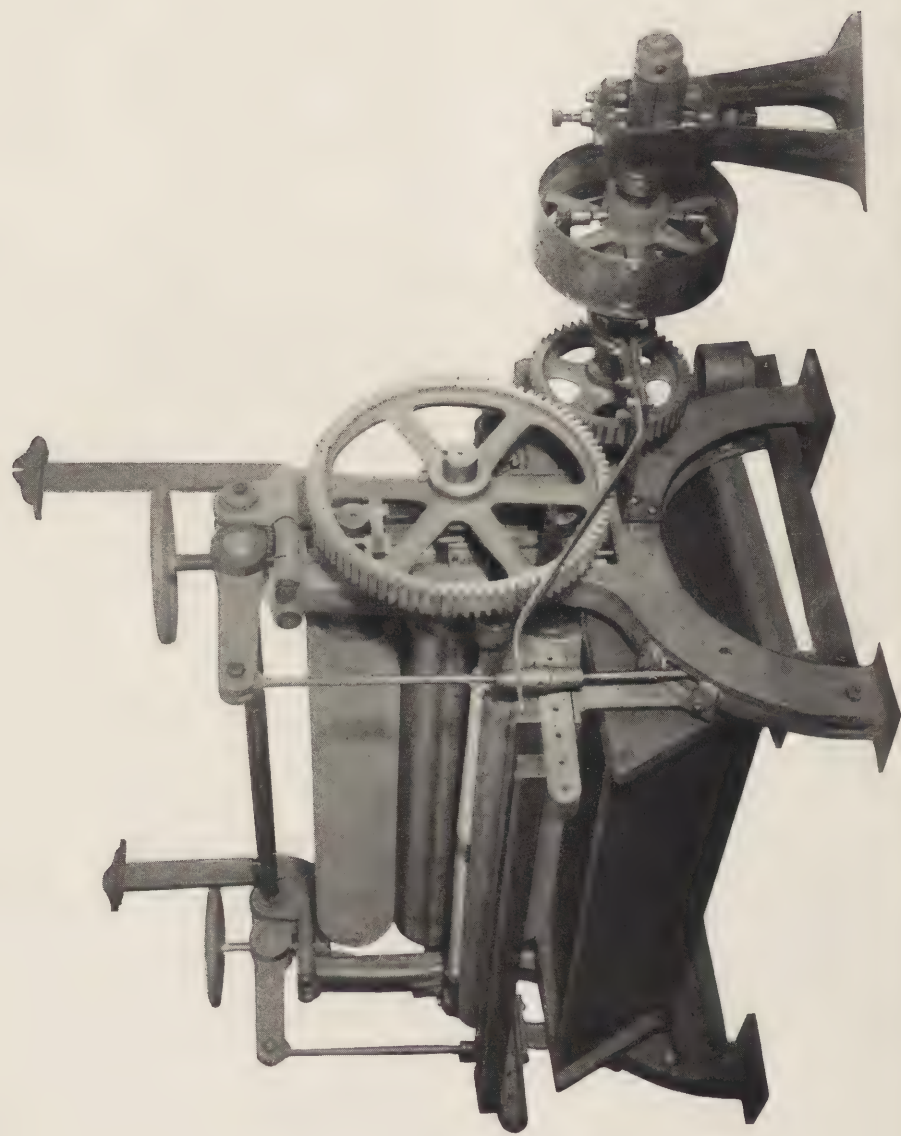


Fig. 51. Can Dryer.

ing is omitted the yarn is commonly boiled in a slightly alkaline bath until thoroughly softened and wet out. If an alkali is used for this purpose the yarn should be washed previous to the dyeing. Bleaching is necessary when the yarn is intended for the production of delicate tints or to be finished as a pure white.

In general, the process of bleaching cotton yarn consists of three essential steps.





THREE-ROLL PADDING MACHINE, DRIVEN BY FRICTION PULLEY, PINION, AND GEAR



(1.) Boiling or scouring in an alkaline solution, usually soda ash or caustic soda.

(2.) Steeping in a dilute solution of bleaching powder.

(3.) Steeping in a dilute acid solution.

This series of operations is always followed by a thorough washing. The methods of carrying out these steps vary only in detail and apparatus used.

**118. Detail of Process and Machinery Used.** The detail of the process varies at different works but depends upon the ideas of the bleachers, the facilities at their disposal and the purposes for which the yarn is to be subsequently used.

The following may be taken as the outline of a typical yarn bleaching process :

(1.) Boil yarn 12 hours in a low pressure kier using soda ash 4% of the weight of the goods. The addition of a small amount of soap materially aids in the removal of the natural impurities. In case a pressure kier is used the period of boiling may be shortened.

(2.) Wash thoroughly.

(3.) Chemick by allowing to remain in a  $1\frac{1}{2}^{\circ}$  to  $2^{\circ}$  Tw. bleaching powder solution (entirely under the surface) for 5 to 6 hours.

(4.) Wash to remove excess of bleaching powder.

(5.) Sour 15 to 20 minutes in  $\frac{3}{4}^{\circ}$  to  $1^{\circ}$  Tw. sulphuric acid solution, or a hydrochloric acid solution of the same density.

(6.) Wash thoroughly, rinse in a mild soap bath, hydro extract and dry. A small amount of blueing is sometimes added to the rinsing bath.

The above will give as thorough a bleach as is necessary for most purposes.

The yarn may be bleached either in the form of skeins or in the chain form, the latter being the term commonly applied to long continuous rope-like bundles of yarn, made up of hundreds of individual yarns, all arranged parallel to each other, and in such a way that they may easily be separated and reeled after the bleaching and dyeing operation is completed.

When in the chain form yarn is easily handled, but in the skein form more difficulty is experienced. It is often the practice

to tie skeins together end to end, thus making a continuous chain.

The boiling is commonly done in low pressure kiers, although some bleachers prefer pressure kiers for this purpose (for description of which see No. 100) and the boiling is continued as long as is necessary.

The washing, scouring, and chemicking is usually done in some form of an open cistern. Fig. 52 illustrates a simple form of cistern which may be conveniently used for washing and also for chemicking and scouring.

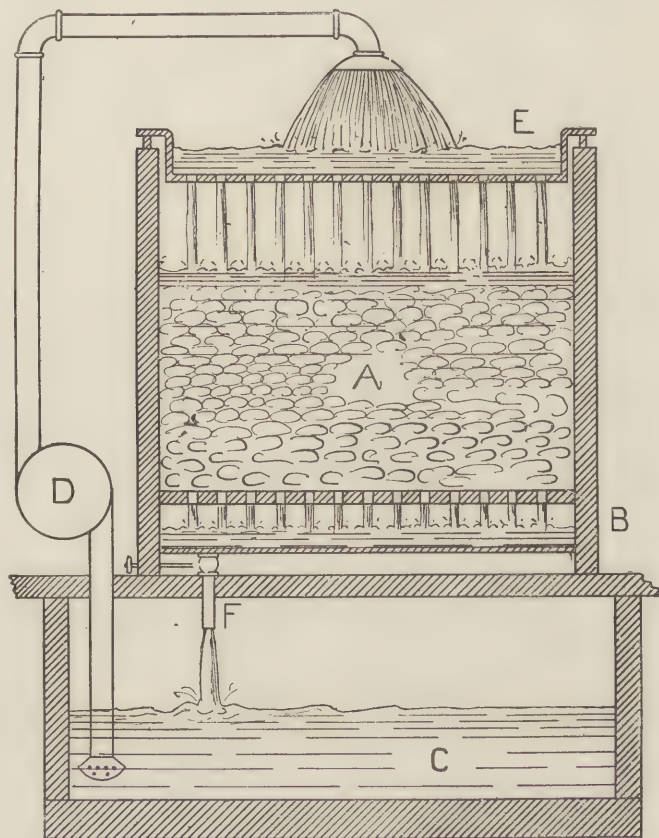
The yarn is carefully packed in the cistern A, which is provided with a false bottom B, a sub-cistern C, containing the water, chemick or acid solution as the case may be, and a rotary pump D, forces the liquid from C to the perforated top E where it is sprinkled even upon the top of the goods and after slowly perculating through the yarn, it returns through the out-let pipe F to the sub-cistern C from which it repeats the circulation. By placing a valve in F it is possible to hold the liquor in A any length of time.

The Mather and Platt arrangement illustrated in Fig. 53 is similar to the apparatus described in Fig. 52 but is so arranged that the lye boil, chemicking, souring and washing may all be done in one and the same cistern, without moving the material, thus saving a great deal of labor and handling. As will be seen from the cut, separate tanks are provided for the various liquors, each of which has its own pump or injector, and system of return pipes.

**119. Bleaching of Raw or Loose Cotton.** Raw or loose cotton is seldom bleached, since about the only finishing products containing cotton in this state are wadding and lint, and there is usually no necessity for bleaching these. Special cases, however, come up from time to time, as for instance the production of a pure white single yarn for filling in cloth that cannot be bleached, for which a varying amount of bleached cotton is required, and the dyer or bleacher should know how to meet these demands.

Cotton bleached in the loose state invariably gives a better white for the same amount of treatment than yarn. This is probably due to the fact that the yarn has taken up oil and dirt during

the spinning. The great drawback in bleaching raw cotton on a large scale is the manner in which wet cotton mats and wads together. A specially constructed kier having perforated diaphragms would have to be used, and it is extremely doubtful if the better bleach obtained would be of sufficient advantage to coun-



No. 52. Bleach Cistern.

teract the difficulties met in the operation. Again, the bleached cotton would be liable to become very much soiled during the spinning and weaving and in many cases would have to be rebleached when finished.

The processes used for bleaching yarn and cloth (already described) cannot be used for bleaching raw or loose cotton on account of the different nature of the material.

The greatest difficulty is experienced in giving the loose cotton the preliminary lye boil which is so efficient in removing the oily and fatty matter from the fiber. In works where there is a frequent demand for bleached cotton, it might be well to have specially constructed baskets or cages that will hold several hundred pounds, and have a traveling pulley over head so that these baskets

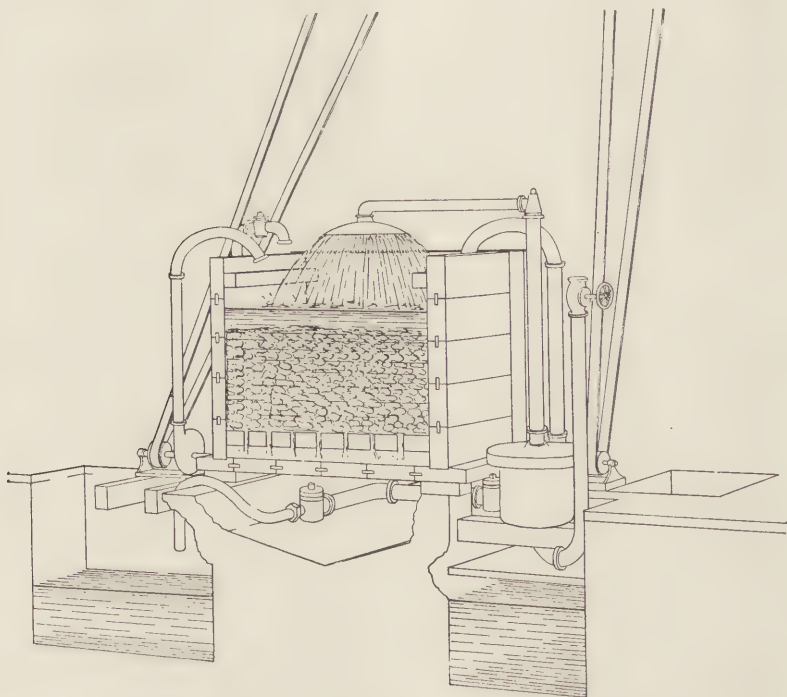


Fig. 53. Mather & Platt Improved Bleaching Cistern.

when filled might be lowered for the necessary length of time into a boiling lye bath, then raised, washed thoroughly and lowered in a bath containing bleaching powder solution, then washed, and into a dilute acid bath and finally given a thorough wash.

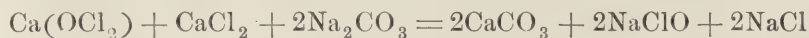
In some cases an alkali boil is given by placing the cotton securely in bags, about 100 lbs. each, and then subjecting a number of these filled bags to a lye boil in a regular kier, and then washing, chemicking, souring and washing in open tanks.

Some bleachers have used regular raw stock dyeing machines successfully for the bleaching of loose cotton.



From laboratory experiments it has been found that the use of sodium hypochlorite solution (slightly alkaline) instead of calcium hypochlorite bleaches loose cotton very satisfactorily and at the same time aids to a considerable degree in the removal of the natural impurities. In fact, by the use of this bleaching agent it is even possible to obtain a bleach satisfactory for most purposes, when the preliminary lye boil is omitted.

A sodium hypochlorite solution may be made by adding concentrated sodium carbonate solution to a bleaching powder solution until no more calcium carbonate is precipitated, adding a slight excess of the sodium carbonate.



When the calcium carbonate has settled, the supernatant liquor may be drawn off, made up to 4° Tw and is ready for use.

An ordinary vat or tub may be used for the bleaching and it is better to do small quantities at a time to prevent matting. The cotton is entered directly into the bath of sodium hypochlorite, and allowed to remain completely under the surface of the liquor for three hours after it has become thoroughly wet out. Sometimes the cotton may be steeped in the bleaching liquor over night, but in this case the strength of the bath should be reduced somewhat.

In the bleaching of cotton yarn and cloth, it is customary to follow the bleaching with an acid treatment or "sour," as it is called, and this is sometimes done in the bleaching of loose cotton, but the thorough washing of cotton in this form is difficult, and as any traces of acid remaining in the fiber would be sure to tender it, sodium bisulphite solution 2° to 3° Tw. or a sulphurous acid solution had better be used to neutralize any free chlorine remaining in the material.

Yarn is often washed by hand in ordinary rectangular tubs, by hanging the skeins on sticks as in the process of dyeing and sometimes in specially constructed machines (Haubolds Yarn Washing Machine) Fig. 54 serving as a good example. It consists of a circular tank over which radiate a large number of horizontal axes each carrying a square bobbin, upon which the yarn is hung.

When the machine is in operation these axes travel completely around the tank at each revolution of the central upright

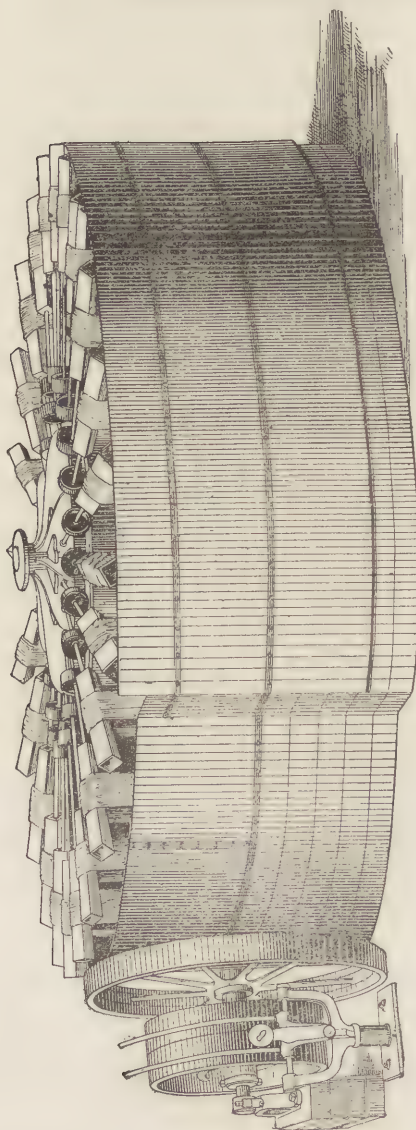
axis, and at the same time revolve independently, thus keeping the yarn in constant motion as it passes through the water.

#### OTHER BLEACHING PROCESSES.

##### 120. The Mather and Platt Steamer Kier Process. Since

1880 a number of chlorine bleaching processes have been proposed, which differ considerably from the old process already described. Some have been carried out on the large scale with more or less success, while others have proved to be positive failures. Of all these, none have met with greater success than that proposed by M. Horace Koechlin about 1887, and carried out in the Mather and Platt Steamer Kier. In this process the lime boil is entirely dispensed with and the lye boils with soda ash replaced by a single boil with caustic soda and rosin soap.

Fig. 54. Yarn Washer.



hydraulic lift L, and which when lowered wedges itself steam

tight into the frame F. In the bottom of the kier is a track T, on which the two trucks or cars CC', can be run in and out. These cars are constructed of galvanized iron; are provided with a perforated bottom and hold the goods during the boiling process. When the goods have been evenly packed in the cars, they are run into the kier, the door is closed and all the air expelled from the kier by the admission of steam. Great care must be taken in this particular, for a bubble of air remaining in the goods may result in local tendering.

Sufficient caustic soda solution is now run into the kier; the steam pressure raised to the proper point, and a constant and positive circulation of the liquor kept up by the pump P, which draws the liquor from the bottom of the kier through the pipe A, forces it through the pipe B, which divides at E, and terminates in the two sprinklers S, and S', which shower the hot caustic

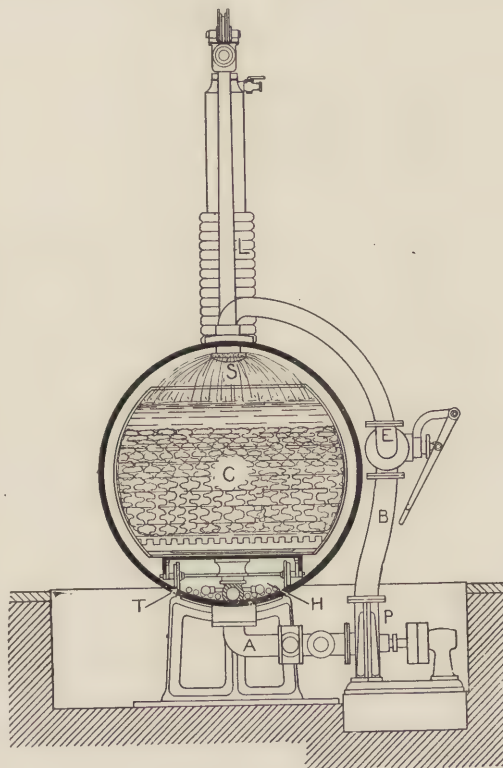


Fig. 55. Mather & Platt Steam Kier.

soda solution over the goods in the cars. The solution leaches through the goods, passes the perforated bottoms, collects in the bottom of the kier where it is heated by a coil of pipes H, and is ready to circulate again. After the boiling, the goods may be easily washed in the kier and the subsequent treatment is the same as that following the lye boils in the Madder bleach, that is, chemicking, souring, final washing and finishing.



In carrying out the process the gray cloth is wet out, sometimes given a sour with sulphuric acid, and allowed to stand in a pile several hours, then washed, saturated with the caustic soda solution and run into the kier.

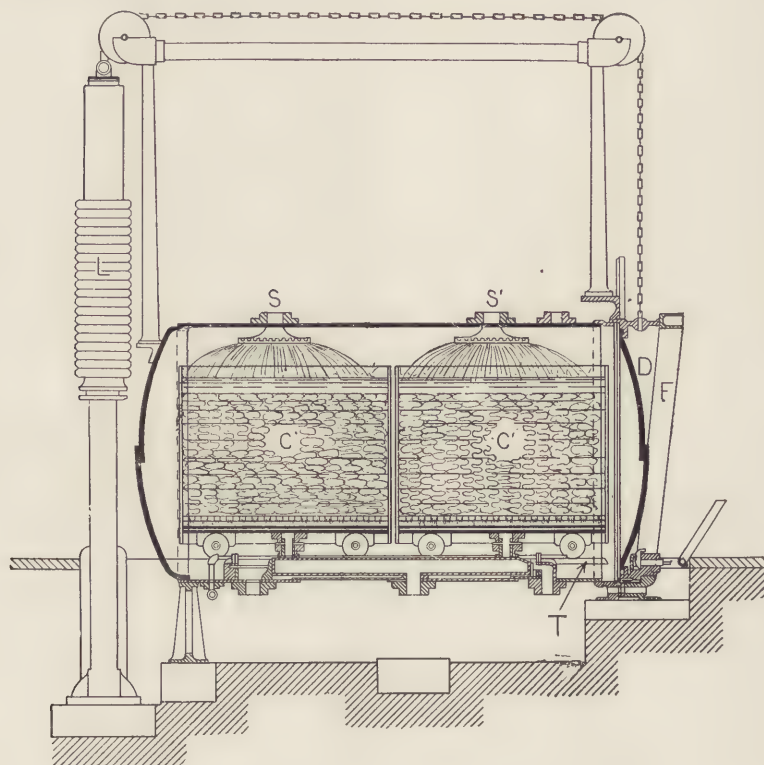


Fig. 56. Another View of Mather & Platt Steam Kier.

The following strength of liquor may be taken as a good example of that in common use.

50 lbs. Caustic Soda. (70%)

30 lbs. Rosin.

425 to 450 gal. of Water.

When first introduced the kiers were run at a pressure of from 7 to 15 pounds, but of late the tendency has been to increase the pressure, often as high as 40 pounds, and the whole bleaching process is sometimes carried out in 24 hours.



Many modifications of this process are made to suit the class of goods being bleached. Often a mixture of caustic soda and soda ash is used and it is possible (and in fact often done with back cloths) to give a lime boil in this kier.

Within a few years an improved form of this kier has been introduced which is constructed to work at a higher pressure, is of

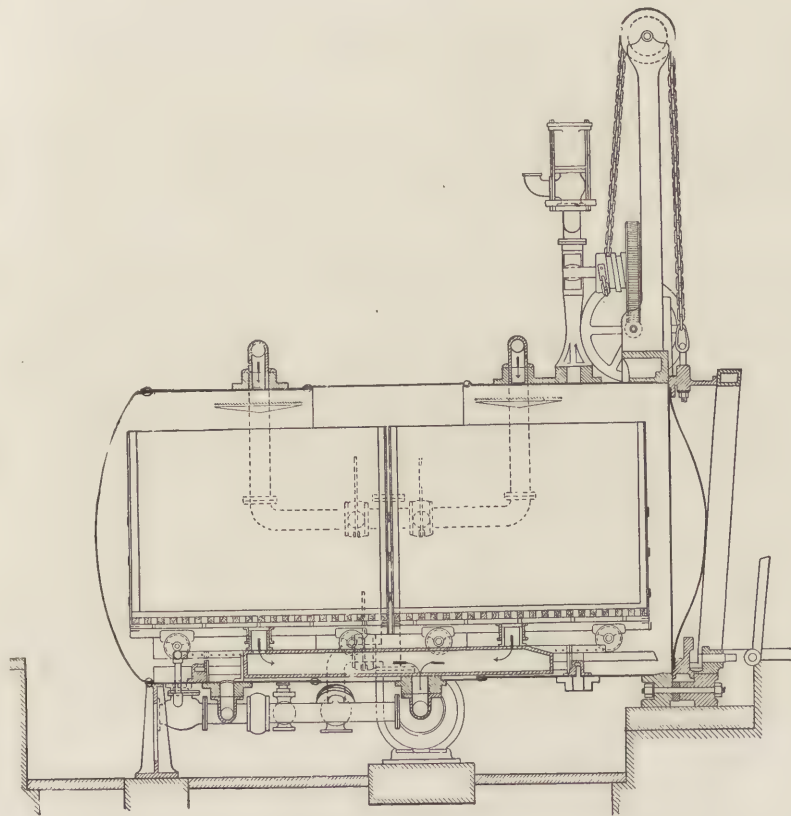


Fig. 57. Improved Form of Mather & Platt Kier.

greater capacity, and provided with a method of raising the door by means of a simple mechanical worm gear instead of a hydraulic ram. A device for producing a partial vacuum in the kier before the introduction of the circulating liquor is added, and also an arrangement for forcing the liquor up through the cloth as well as down. Fig. 57 shows the new type of kier.

The Mather and Platt Steamer Kier seems to be giving great success in many places and it certainly is a clever device for saving time and producing positive circulation of the bowking liquor.

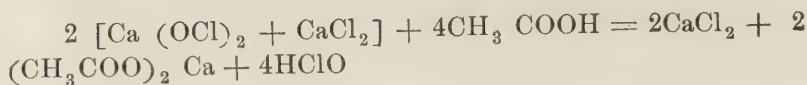
**121. Electrolytic Bleaching Processes.** At the present time it is not uncommon to hear mention made and to see in the current Textile literature, articles in regard to the application of electricity in bleaching processes. None of these have apparently met with sufficient success to insure their adoption by more than here and there a progressive concern ready to experiment with the latest devices, and even at these places they are not depended upon entirely.

These Electrolytic Processes may be divided into two classes: First: those in which the hypochlorite solution is formed directly in the electrolytic apparatus, and second, those in which the chlorine is formed and then conducted away and used to produce a hypochlorite solution in another apparatus. Of the former the "Hermite Process" is probably as representative as any. In this a solution of magnesium chloride, or a mixture of magnesium chloride and sodium chloride is electrolyzed.

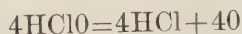
Among the best representatives of the second class are the "Le Sueur Process" and the "Castner Process." Both of these consist in the electrolysis of sodium chloride solution, with the production of free chlorine and metallic sodium, the latter uniting with water to form caustic soda.

**122. Other Bleaching Processes Using Chlorine.** Among the other bleaching processes using chlorine may be mentioned the Mather and Thompson continuous process. It consists in giving the cloth the necessary lime and lye boils and completing the bleaching by passing through a special bleaching chamber consisting of a dozen or more separate compartments, containing water, bleaching powder solution, and carbonic acid gas, and before leaving the apparatus, through a compartment containing dilute (1%) hydrochloric acid. It takes the cloth three to five minutes to pass through the apparatus and the special feature is use of carbon dioxide as a souring agent or liberator of chlorine.

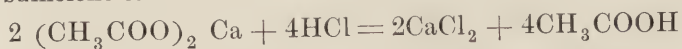
Mention might also be made under this head of Lunge's process of using a mixture of acetic acid and bleaching powder solution. The reaction upon mixing the two is



followed by



The hydrochloric acid liberated in the last reaction is theoretically just sufficient to liberate the acetic acid from the calcium acetate.



Thus the amount of acetic acid used at the beginning of the operation with a small addition now and then is sufficient to carry

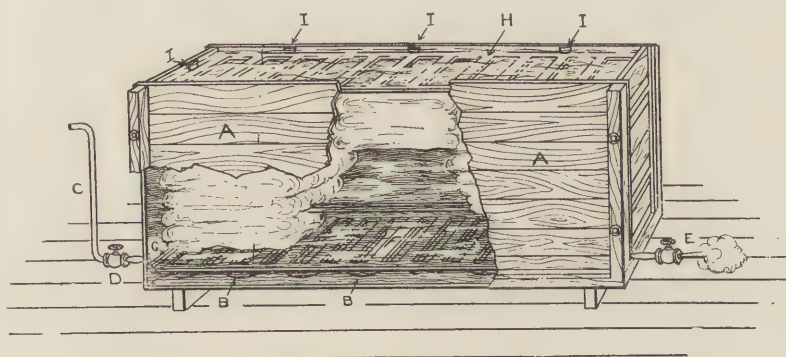


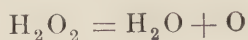
Fig. 58.

on the reaction of liberating the chlorine for a long time. It is claimed that by using this process the white sour is unnecessary.

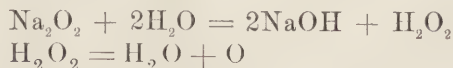
#### BLEACHING WITHOUT CHLORINE.

**123. Bleaching with Hydrogen Peroxide and Sodium Peroxide.** In No. 111 the active bleaching power of nascent oxygen was described and mention made that certain peroxides particularly those of Hydrogen and Sodium were excellent bleaching agents because of the ease with which they liberated nascent or atomic oxygen.

Hydrogen peroxide decomposes readily, even upon standing, liberating nascent oxygen and forming water according to the equation,



So also sodium peroxide when added to water is readily decomposed, forming sodium hydroxide or caustic soda, hydrogen peroxide and finally nascent oxygen.



The large amount of heat developed during this reaction in conjunction with the strong alkalinity of the bath, cause a rapid evolution and consequent loss of oxygen and if nothing were done to check this action, the greater part of the available oxygen would rapidly escape into the air and be entirely lost as far as any bleaching action were concerned.

In the case of textile materials of animal origin for which hydrogen peroxide is also well adapted, the strong alkalinity would have a serious deteriorating action.

This objectionable action of the caustic soda may be counteracted, and a gradual and uniform evolution of oxygen brought about by first adding to the bath just enough acid, usually sulphuric, to neutralize the caustic soda that will be formed during the addition of the sodium peroxide.

The best results are obtained when the total amount of acid necessary for the neutralization is added to the bath first followed by the sodium peroxide in small quantities with constant stirring. The reaction taking place is represented as follows:



The sodium sulphate ( $\text{Na}_2\text{SO}_4$ ) formed remains in the bath but in no way interferes with the process and is wholly without action upon the material, if a thorough washing follows the bleaching.

The Roessler & Hasslach Chemical Company of New York have been foremost in the introduction of sodium peroxide as a bleaching agent, and they recommend the following process for bleaching vegetable fibers, which is based upon both experiment and practice and which has been applied successfully in many cases. A convenient form of apparatus is represented in Fig. 58.

The wooden vat A, is provided with a lead heating pipe B, coiled along the bottom and connected with the iron steam supply pipe C, by means of a valve and wiped joint D. The steam exhausts at the valve E, after passing through the heating coil B.



Over the coil B, is a false bottom F, held down by wooden cleats G, which are fastened with wooden pins. The material is held under the surface of the bleaching solution by the wooden frame H, fixed in place by the wooden wedges I. No metal except lead should come in contact with the bath. A safety valve may be attached at E, to avoid the possibility of bursting the pipe in case the outlet valve is not opened when the steam is turned on.

When using wooden vessels for the first time, they should be boiled out with soda, rinsed with hot water and regular peroxide bleaching solution allowed to stand in them for some hours or over night. This will prevent the color coming out of the wood and staining the cloth.

After whatever preliminary treatment as is deemed necessary, the goods are washed and entered into a bleaching bath made as follows: To every 100 gallons of water add

5½ lbs. Sulphuric (66° Be.)

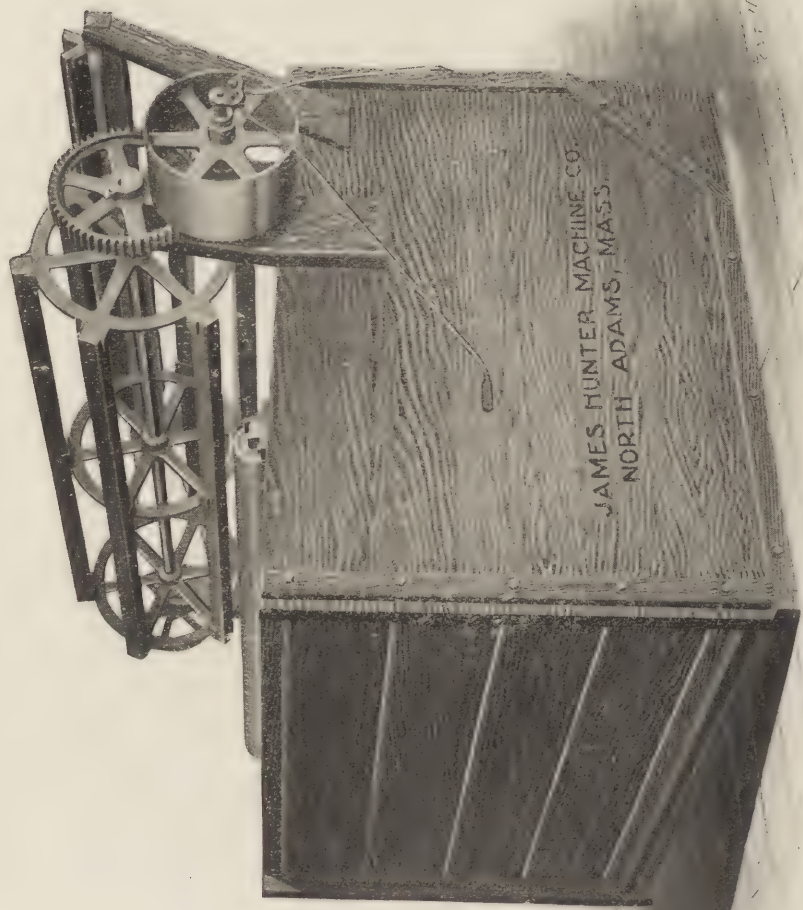
and then 4 lbs. Sodium Peroxide, little by little,

and with constant stirring until the bath gives a slight blue color to litmus paper. If the paper does not turn blue after all the sodium peroxide has been added, add ammonia (only a little needed) until it does. Should the bath become too alkaline add a very little acid.

Enter the material, heat to 120° F, from one to two hours depending upon the nature of the goods. Lift, drain allowing liquor to return to vat, and then rinse thoroughly. Succeeding batches are entered at once, allowing more time to each, but without strengthening or restoring the bath, which is finally exhausted by leaving the last batch to bleach over night.

Great care must be taken to prevent any iron from coming in contact with the bleaching liquor.

Until within a few years the expense of bleaching by the use of peroxides has been so great as to rule them out for only very special cases, but of late, improvements in the process of making sodium peroxide has reduced the cost materially. For many purposes sodium peroxide is now found to be a valuable and not too expensive bleaching agent. Its value in the bleaching of union goods cannot be overestimated.



**REEL DYEING MACHINE**

The James Hunter Machine Co.

# TEXTILE CHEMISTRY AND DYEING.

## PART III.

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### EDUCATIONAL REQUIREMENTS OF THE TEXTILE COLORIST.

124. To become an efficient dyer one should have a knowledge of the material to be colored, its chemical and physical properties, its structure, and its action with the various reagents with which it may come in contact during the coloring process. Furthermore, it is essential that the dyer be well acquainted with the properties of different dyestuffs, and that he know, as far as possible, their composition, but more particularly their action toward the different fibers under various conditions.

The former consideration we have taken up with considerable detail; and, having brought the material to where it is ready to be colored, we shall take up the latter consideration.

### PRINCIPLES OF TEXTILE COLORING.

125. **Textile Coloring** may be defined as the process, or combination of processes, used to fix a color or colors permanently and uniformly upon textile material, and includes both dyeing and textile printing.

**Dyeing** is sometimes given almost as broad an interpretation as textile coloring; but, to be specific, it should include only those processes in which *the entire body* of the material that is being colored is immersed in the coloring bath for a greater or less period of the time required for the coloring.

**Textile Printing** is a process by which the colors are confined, by use of a printing machine, to certain *portions* of the

material, thus producing a definite colored design. The color paste is applied by means of copper rollers, one for each color; and often prints containing ten or more different colors are produced. In some cases mordants are printed upon the material, and the colors developed later by a dyeing process. Many different effects may be produced by combined dyeing and printing.

The coloring of such materials as paper, leather, straw, feathers, bone, wood, and ivory — which, strictly speaking, are not textile materials — is more commonly designated as **Staining** than as dyeing.

### CLASSIFICATION OF DYESTUFFS.

**126.** The first classification of dyestuffs was made about one hundred years ago by Bancroft, one of the earliest color chemists. He divided the dyestuffs then existing into two classes, **Substantive** and **Adjective**.

As **substantive dyestuffs** he designated those capable of producing a full shade upon textile material without the necessary assistance of any other combining substance; and as **adjective dyestuffs** those requiring an intermediate combining substance (called a **mordant**) to fix satisfactorily and fully develop the color.

This classification has been used ever since, but of late there has been a constant tendency to replace the term "substantive dye" with that of **direct color**, and "adjective dye" with the term **mordant color**.

As examples of substantive or direct colors, we might mention turmeric, indigo, and the direct cotton colors; and as examples of adjective or mordant colors, alizarine and related dyestuffs, logwood, and fustic.

The above classification is not entirely satisfactory, there being many dyestuffs that are substantive toward one fiber and adjective toward another. The basic colors, for instance, are substantive toward wool fiber but adjective toward cotton; while the acid colors are substantive toward wool but have no direct affinity for cotton. Again, there are the insoluble azo colors, like the common Para and Naphthylamine reds, that cannot in the truest sense be considered as belonging to either class.







SECTION OF PRINTING ROOM, SHOWING 19 MACHINES IN OPERATION

Another common method is to classify dyestuffs according to their source into

- (1) Natural Dyestuffs:
  - (a) Vegetable.
  - (b) Animal.
- (2) Mineral Dyestuffs.
- (3) Artificial Organic Dyestuffs.

Though the various divisions of this classification, particularly the artificial, are quite sweeping in the number and character of the dyestuffs they include, they have the advantage of conciseness, and one class does not overlap another.

The natural dyestuffs include such coloring matters as logwood, indigo, fustic, cutch and cochineal.

The mineral colors include prussian blue, chrome yellow, iron buff, and a large number of inorganic pigments.

The artificial organic dyestuffs are the most important, and this class may be divided into twenty or more important sub-classes. It includes all of the so-called coal-tar dyes, such as magenta, benzo-purpurin, acid violet, tartrazine, alizarine, etc.

It is this latter classification that we shall follow.

### THEORIES OF TEXTILE COLORING.

127. There are three theories in regard to the nature of textile coloring processes, which are definite enough to be named. They are as follows :

1. The Mechanical Theory.
2. The Chemical Theory.
3. The Solution Theory.

The **mechanical theory** assumes that the various coloring matters are fixed to the fiber by purely mechanical means.

The **chemical theory** assumes that there is a direct chemical combination between the dyestuff and the fiber.

The **solution theory**, the most modern of the three, was proposed by the German color chemist, Dr. Otto Witt. It was originally proposed as an explanation of the dyeing of direct cotton colors, but applies to all substantive dyestuffs. This theory assumes that a cotton fiber dyed with a direct cotton color—or in fact any fiber dyed with a purely substantive color—is a solid solution of the dyestuff.

The true nature of the dyeing process is, as yet, a conjecture in most cases. In some instances there is strong evidence of chemical union between dyestuffs and fiber; while in others — as, for instance, the fixation of pigments in calico printing — mechanical principles are evident. In the case of color lakes like turkey red, no one doubts that the color is developed by the chemical union of alizarine with aluminium and, perhaps, a little calcium; but this color lake is probably held in the pores and attached to the fibers mechanically rather than by chemical combination. In the case of the direct colors, the solution theory is a reasonable explanation; but the fact that an alteration in the chemical composition of a fiber often noticeably influences its affinity for dyestuffs, is strong evidence in favor of the chemical theory. The establishment of the true theory of dyeing is therefore an open question; and with these facts in mind, together with many others that will be learned through study and practice, each student will gradually establish a theory of his own.

#### DEFINITIONS.

**128. Mordants.** A mordant may be defined as a substance capable of uniting with certain dyestuffs to form insoluble colored compounds (usually color lakes) which, under certain conditions, will become attached to or united with textile material.

**Color Lakes.** A color lake is an insoluble colored compound produced by the chemical union of an organic compound with an inorganic substance (usually an oxide or a hydroxide of a metal).

*Example.* The organic substance alizarine unites with the hydroxide of aluminium and calcium to form a valuable color lake known as Turkey red.

**Pigments.** A pigment is any insoluble compound, usually colored, in a very finely divided or powdered state. Most pigments are of inorganic origin, as lead chromate ( $\text{PbCrO}_4$ ), cinabar ( $\text{HgS}$ ), and chromium sesquioxide ( $\text{Cr}_2\text{O}_3$ ); but the term also includes the color lakes and such substances as para red, indigo blue, lamp black, and sepia, which are of organic origin.

**Mordanting Process.** This is the operation by which various mordants are precipitated or fixed upon textile material, in order that they may unite with coloring matters to form color lakes.



**Mordanting Principle.** As often applied, the term "mordant" indicates the metallic salt used to produce the mordant; but in the strictest sense, the mordant is that compound which, in direct combination with the dyestuff, forms the color lake. In order to avoid confusion, we shall designate the compound used to produce the mordant as the **Mordanting Principle**.

*Example.* In one of the most important wool mordanting processes, potassium bichromate ( $K_2Cr_2O_7$ ) is used in the mordanting bath; but the actual mordant precipitated upon the fiber is an acid oxide of chromium ( $CrO_3$ ).

The potassium bichromate is, therefore, the mordanting principle.

**Fixing Agents.** The term "fixing agent" is frequently used in an indefinite sense, and, as commonly applied, leads to confusion rather than enlightenment. The misunderstanding arises through the difficulty experienced in making a precise division between a true mordant and a fixing agent. By strict adherence to the following classification, which recognizes six distinct classes of substances, the writer believes that little if any misunderstanding can arise.

- (1) Metallic Mordants.
- (2) Acid Mordants.
- (3) Chemical Fixing Agents.
- (4) Mechanical Fixing Agents.
- (5) Developing Agents.
- (6) Mordanting Assistants.

(1) **Metallic Mordants.** This term is used to include only substances (usually metallic oxides or hydroxides) which, in chemical union with certain dyestuffs known as "Mordant Colors," will produce color lakes.

(2) **Acid Mordants.** This term includes tannic acid and the various substances rich in this acid (such as sumac, gall nuts, and various bark extracts), various fatty acids (such as oleic and stearic acids), and Turkey red oil — all of which are of an acid character. These compounds, when used in conjunction with the basic dyestuffs, cause, by chemical union or otherwise, a relatively fast deposition of coloring matter upon cotton, a fiber for which they alone have but little affinity. The acid mordants are of minor importance as compared with the metallic mordants.

(3) **Chemical Fixing Agents.** This term is used to include only the following classes of compounds:

(I) Those which are instrumental in the fixation of a mordant upon textile material by uniting chemically with the mordant and holding it there in an insoluble condition until such time as the proper dyestuff shall be ready to react with it.

*Examples.* (a) The various antimony compounds used to fix tannic acid upon cotton fiber as an insoluble antimony tannate, previous to dyeing with basic colors; (b) The tannin compounds (as sumac) used to fix iron upon cotton and silk in the form of an insoluble tannate of iron, when the iron is to be used as a mordant for logwood.

(II) Those which cause the precipitation of the actual mordant upon the fiber when the material already saturated with the mordanting principle is passed through a solution of the fixing agent.

*Example.* If cotton material saturated with a solution of nitrate of iron (mordanting principle) is passed through a solution of sodium carbonate (fixing agent), the latter reacts with the former, precipitating iron as a basic carbonate or hydrate and thus fixing an iron mordant upon the fiber.

In a number of cases, compounds precipitated in this way have a decided color, and material may be allowed to remain in this condition without dyeing. In the example cited, for instance, a brownish-yellow shade known as "iron buff" is produced.

(4) **Mechanical Fixing Agents.** This term is used to include any substances (such as albumen and certain gums) capable of holding pigments permanently upon textile material by mechanical means.

*Example.* In calico printing, a pigment like chrome yellow may be made into paste with albumen solution, and printed upon cotton material. Upon steaming, the albumen coagulates, becomes insoluble in all ordinary reagents, and the color is permanently held upon the fiber.

(5) **Developing Agents.** This term includes any organic substances capable of uniting with other substances (sometimes a dyestuff already upon the fiber) to produce an insoluble colored organic compound or pigment, not a color lake.

*Examples.* (a) Cloth prepared with Beta naphthol, when passed through a bath of diazotized para nitro-aniline, will become dyed a beautiful red, by the formation of an insoluble red pigment throughout the material. In this case the diazotized para nitro-aniline is the developing agent.

In case the substance already upon the fiber is a dyestuff, the operation is commonly called the **coupling process**, and is to render the original shade faster. Usually the original shade is retained, but in some cases it is modified or changed completely.

(b) If cotton material dyed with Primuline, a direct cotton yellow, is diazotized and passed through a solution of Beta naphthol, the Primuline will become coupled with the latter, and a bright red will be produced.

(6) **Mordanting Assistants.** Under this head should be included such substances as tartar (potassium acid tartrate) and lactic, oxalic, and sulphuric acids, which are often used in metallic mordanting baths. They assist in the uniform deposition of the mordant upon the fiber, but are not themselves taken up by the fiber and in no way enter into the final color lake.

### APPLICATION OF MORDANTS — General.

129. The periods of the coloring process at which the mordant may be applied are as follows :

(1) *Previous to its union with the color stuff.* This is by far the commonest and most important time of application. In this case the mordant is applied to the material in one bath, and the color stuff applied later in a separate bath.

(2) *In conjunction with the color stuff.* This is very common in textile printing processes. Processes have also been devised in which both mordant and color stuff are used in the same bath; but they are few in number and for the most part unsatisfactory, there being too great a tendency for the color lake to form and precipitate in the bath rather than upon the fiber.

(3) *The color stuff applied first and the mordant subsequently.* This process is sometimes called **stuffing** or **saddening**, but more frequently, **after treating**. When a chromium compound is used, which is often the case, the process is known as **after-chroming**.

In general it may be said that the mordanting process consists in treating the fiber in some way with a soluble compound of a metal (mordanting principle) which is decomposed in the case of animal fibers, by the presence of the fiber itself or through dissociation by solution in the mordanting bath, the oxide or hydroxide of the metal becoming fixed upon the fiber. In the case of vegetable fibers, which differ greatly from those of animal origin in character, the mordant becomes attached to the fiber more through chemical precipitation and fixation.

**The Mordanting process is of great importance**, as the mordant plays almost as necessary a part in the application of the so-called mordant colors as does the dyestuff itself, and among this class are included some of the most valuable of color stuffs.

Of all the metals, only a few are valuable as mordants. These are: Chromium, aluminium, iron, copper and tin. On account of its general applicability, chromium is most frequently used. Iron



and copper seem to produce the fastest color lakes, while aluminium and tin form the brightest.

Combinations of two mordants are frequently used, particularly in textile printing, thus producing a great variety of shades. Such compounds as the oxides of calcium, magnesium, and zinc, though of little value alone, often increase the fastness of the color lakes of other mordants. They are sometimes spoken of as being **supplementary mordants**.

**130. Mordanting of Wool.** The chemistry of the mordanting of wool is not only complicated but more or less theoretical. For the present, therefore, we shall let the following points suffice:

Wool apparently has more or less natural attraction for certain compounds both basic and acid in character. When in dilute solution, the highly dissociated condition of the mordanting principle, aided by this natural affinity of wool, brings about a deposition of various metallic compounds (usually oxides or hydroxides) upon the fiber, which depend in their composition chiefly upon the mordanting principle used, but to a certain degree also upon the other conditions of the mordanting bath. This process takes place most completely and uniformly in a boiling bath, and in the presence of some other soluble compound which we have already described as a "mordanting assistant."

**Chromium Mordants on Wool.** The present methods of applying mordant colors to wool, especially for the production of dark shades, depend almost entirely upon the use of chromium mordants. *Potassium bichromate* ( $K_2Cr_2O_7$ ) is the most important chromium mordanting principle.

When wool is boiled in a plain dilute solution of potassium bichromate, decomposition appears to take place as follows:

$$K_2Cr_2O_7 = K_2CrO_4 + CrO_3$$

Potassium Bichromate = Potassium Chromate + Chromic Anhydride,

the chromic anhydride in some way combining with the wool, and the potassium chromate remaining in solution.

It is the *basic oxide of chromium* ( $Cr_2O_3$ ), however, which seems to be the most valuable as a mordant, except, perhaps, in the case of the application of some logwood extracts. In dyeing with alizarines as well as other mordant dyestuffs, if much  $CrO_3$  is



present, it is reduced to  $\text{Cr}_2\text{O}_3$  at the expense of the dyestuffs, which is, of course, an expensive method and which furthermore detracts from the brilliancy and general tone of the finished color by the formation of a greater or less amount of some muddy-appearing oxidation product of the dyestuff.

The mordanting of wool in a plain potassium bichromate bath is, therefore, not practicable in the majority of cases.

In order to reduce as much of the  $\text{CrO}_3$  to  $\text{Cr}_2\text{O}_3$  as is necessary, and to bring the deposition about slowly and uniformly throughout the wool, a mordanting assistant is added to the mordanting bath. The substances most frequently used for this purpose are:

Tartar (*Bitartrate of Potassium*,  $\text{KHC}_4\text{H}_4\text{O}_6$ ),  
Lactic Acid ( $\text{C}_2\text{H}_4\text{OH.CO OH}$ ),  
Oxalic Acid ( $\text{CO OH}$ )<sub>2</sub>.

The following may be taken as representative wool-mordanting processes in which potassium bichromate is used as the mordanting principle:

METHOD A. *Potassium bichromate alone.*

2 per cent —  $\text{K}_2\text{Cr}_2\text{O}_7$ . For light shades.  
3 per cent —  $\text{K}_2\text{Cr}_2\text{O}_7$ . For medium shades.  
4 per cent —  $\text{K}_2\text{Cr}_2\text{O}_7$ . For dark shades.  
Necessary amount of water.

Boil material in this bath one and one-half hours.

NOTE. The percentages given above, as well as those which may follow, refer to the amount of material being mordanted or dyed, unless otherwise specified.

METHOD B. *Potassium bichromate and Sulphuric acid.*

3 per cent —  $\text{K}_2\text{Cr}_2\text{O}_7$  } For light shades.  
1 per cent —  $\text{H}_2\text{SO}_4$  }

and

4 per cent —  $\text{K}_2\text{Cr}_2\text{O}_7$  } For heavy shades.  
 $1\frac{1}{2}$  per cent —  $\text{H}_2\text{SO}_4$  }  
Necessary amount of water.

Enter at  $140^\circ$  to  $150^\circ$  F. Bring to a boil, and boil for one and one-half hours.

METHOD C. *Potassium bichromate and Tartar.*

3 per cent — Potassium bichromate.  
 $2\frac{1}{2}$  per cent — Potassium bitartrate.  
Necessary amount of water.

These are the ordinary proportions. For very dark shades the quantities may be advantageously increased to 4 per cent  $\text{K}_2\text{Cr}_2\text{O}_7$  and 3 per cent Tartar; and for light shades the quantities may be reduced to 1 per cent  $\text{K}_2\text{Cr}_2\text{O}_7$  and 1 per cent Tartar.

Enter at 130° to 140°F; bring slowly to a boil; and mordant at a boil for one and one-half hours, working the material well, particularly during the first part of the operation.

METHOD D. *Potassium bichromate and Lactic acid.*

FOR LIGHT SHADES.	FOR ORDINARY SHADES.	FOR VERY DARK SHADES.
1 per cent	3 per cent	4 per cent — $K_2Cr_2O_7$
1 per cent	2 per cent	3 per cent — Lactic acid.
Necessary amount of water. Process same as Method C.		

METHOD E. *Bichromate of potash and Oxalic acid.*

FOR LIGHT SHADES.	FOR ORDINARY SHADES.	FOR VERY DARK SHADES.
1 per cent	3 per cent	4 per cent $K_2Cr_2O_7$
$\frac{1}{2}$ per cent	$1\frac{1}{2}$ per cent	2 per cent — $H_2C_2O_4$
Necessary amount of water. Process same as method C.		

Of the above mordanting processes, A and B cannot be used to advantage, except in cases where an oxidizing mordant is desired.

Method C is the favorite, particularly for light shades where results rather than cheapness are desired. It gives a clean bath, and the finished colors are very clear. For dark shades, crude tartar (argols) is sometimes used to reduce cost.

Method D also gives excellent results, particularly for dark colors, and is comparatively cheap.

Method E gives excellent results in certain cases.

With all these methods, it is best to start the mordanting at a comparatively low temperature — say 130° to 140°F — and to bring slowly to a boil. The various ingredients of the bath should be dissolved separately, for when introduced in the concentrated form they will react with each other, precipitating the mordant in the dye bath rather than on the fiber. If the material is introduced at a boiling temperature, or is heated too rapidly, it is likely to be precipitated on the fiber too rapidly, producing lack of penetration and causing unevenness of coloring. The material should be well worked, particularly at the beginning of the operation; and the amount of mordanting liquor should be from 30 to 50 times the weight of the material that is being mordanted.

After the mordanting, the material should be well washed to remove any excess of mordant not well fixed upon the fiber; other-

wise a superficial color lake will be formed during the dyeing. Finally, the material should be well hydro-extracted and, if possible, dyed without drying.

**Sodium Bichromate** ( $\text{Na}_2\text{Cr}_2\text{O}_7$ ) acts the same as potassium bichromate in nearly every case, and on account of its cheapness is used instead of the latter. It does not crystallize as well, nor keep as well when stored, as the potassium compound. For wool-dyeing, preference is commonly given to the potassium salt.

*Chrome alum* [ $\text{K}_2\text{Cr}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}$ ] and *Chromium sulphate* [ $\text{Cr}_2(\text{SO}_4)_3$ ] are now seldom used as wool-mordanting principles. They are, however, valuable in the preparation of other chromium mordanting principles. *Chromium fluoride* ( $\text{CrF}_3$ )\* has been introduced recently as a mordanting principle, and is meeting with much favor, particularly in cases where the strong oxidizing action characteristic of the potassium bichromate is undesirable. It deposits the mordant readily and uniformly as  $\text{Cr}_2\text{O}_3$ ; and some spinners say that it does not affect the feel and spinning qualities of the wool as much as some other mordanting principles. Chromium fluoride is also used for after-chroming, and with alizarine in wool-printing.

The following method of mordanting wool with Chromium fluoride gives very good results:

3 to 4 per cent—Chromium Fluoride.

1 to 2 per cent—Oxalic Acid.

Necessary amount of water.

Enter at  $140^\circ\text{F}$ ; bring to a boil; and mordant at a boil one and one-half hours.

*Chromium Acetates* are used to a limited extent with wool, particularly in printing, but chiefly in the printing and dyeing of cotton, and will be considered under the latter head.

**Aluminium Mordants on Wool.** Aluminium mordants on wool are not used now as much as formerly. About their only standard uses at the present time are for the production of alizarine reds, pinks, and oranges, cochineal reds, logwood blues, with the yellow natural dyestuffs, and with mixtures of the preceding colors.

\*NOTE.—Chromium fluoride should be stored in wooden containers, as it readily attacks glass and metals. When used in dyeing apparatus made of copper, a small sheet of zinc hung in the bath will prevent corrosion.

The presence of iron will detract from the brightness of the shades produced upon an aluminium mordant, especially with alizarine colors.

Alum and Aluminium Sulphate  $[\text{Al}_2(\text{SO}_4)_3]$  are the only aluminium mordanting principles commonly used with wool. Aluminium fluoride  $[\text{AlF}_3]$  gives good results, but is not used in practice.

The alums are a series of compounds having the general formula

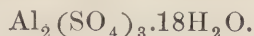


in which  $\text{R}'$  is a metal having a valence of 1, and  $\text{R}'''$  is a metal having a valence of 3. These salts crystallize well and easily, and for this reason are usually very pure. Owing to their reliability, they are largely used in mordanting and in the preparation of other aluminium compounds.

The commonest aluminium alums are the potassium alum  $[\text{K}_2\text{Al}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}]$  and the ammonium alum  $[(\text{NH}_4)_2\text{Al}_2(\text{SO}_4)_4 \cdot 24\text{H}_2\text{O}]$ .

It is only the  $\text{Al}_2(\text{SO}_4)_3$  contained in the alum that is of value in the mordanting process, the potassium sulphate not entering into the reaction at all.

In the past, alum was used in preference to the straight  $\text{Al}_2\text{SO}_4$ ; but during recent years improvements in the process of manufacture have brought out an aluminium sulphate, which, in most cases, is quite free from iron, and which, being of lower cost, has largely superseded alum. It crystallizes as follows:



There is a marked tendency for aluminium salts when in solution, especially at high temperatures, to change gradually from normal to basic salts with the liberation of free acid. This change takes place to a greater extent when wool fiber is present in the solution: an insoluble compound of aluminium is deposited upon the fiber, and, upon boiling, the wool becomes mordanted with  $\text{Al}(\text{OH})_3$  or  $\text{Al}_2\text{O}_3$ . This process goes on with such ease that unless some acid or acid salt is added to retard the process, the mordant will be deposited unevenly. Oxalic acid and tartar are most frequently used for this purpose. They form salts of



aluminium which, possessing greater stability than the aluminium sulphate, dissociate more slowly, in this way causing a more even deposition of the mordant, which, after washing and drying, appears to be the oxide of aluminium ( $\text{Al}_2\text{O}_3$ ).

#### PROCESS:

##### FOR LIGHT SHADES.

or, 5 per cent  
 3½ per cent  
 1½ per cent  
 or, 1 per cent

to  
 “  
 “  
 “

##### FOR DARK SHADES.

10 per cent — Alum  
 7 per cent — Aluminium Sulphate  
 3 per cent — Tartar  
 2 per cent — Oxalic Acid.

Necessary amount of water.

Enter the material (wool) at 85° F; bring to a boil; and mordant at a boil one and one-half hours.

Some dyers prefer to increase the amount of tartar and diminish or entirely do away with the oxalic acid.

**Iron Mordants on Wool.** Iron mordants can be used only for the production of blacks and very dark shades of violet and brown. Of recent years, chromium has largely replaced iron in wool mordanting; and at the present time the latter is but little used in wool-dyeing except for the production of logwood blacks, and as a saddening or after-treating agent.

*Ferrous sulphate* ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), commonly called “copperas,” is the most important iron mordanting principle used with wool. It is chiefly used either alone or with copper sulphate, in the production of logwood blacks. It can be applied *previous to dyeing*, by boiling the wool in a bath made up with ferrous sulphate, oxalic acid, and tartar; *at the same time as the dyestuff*, in a bath made up with  $\text{FeSO}_4$ , oxalic acid and logwood; or *after the dyeing*, as a saddening or after-treating agent. For further discussion see “Logwood on Wool.”

**Tin Mordants on Wool.** Tin mordants are sometimes used for the production of bright cochineal reds and bright yellows, with the yellow natural dyestuffs. When used alone, tin mordants are of minor importance in the coloring of wool. Their value lies chiefly in the fact that when used in conjunction with other mordants the brilliancy of the resulting color lake is greatly increased. For this reason tin mordants are often used with those of aluminium for the production of bright reds.

*Stannous chloride* ( $\text{SnCl}_2$ ) is the tin compound most frequently used as a mordanting principle for wool. Wool boiled in a solution of stannous chloride in the presence of oxalic acid or potassium bitartrate, becomes mordanted with the oxide of tin. With tin mordants the dyestuff is often applied in the same bath.

*Stannic Chloride* ( $\text{SnCl}_4$ ) is sometimes used in wool printing.

**Copper Mordants on Wool.** Like the compounds of tin, those of copper are rarely used alone in wool mordanting. Tin increases the brilliancy of color lakes into which it is introduced, but diminishes their fastness. Copper, on the other hand, when introduced into color lakes, diminishes their brilliancy but increases their fastness.

*Copper sulphate* ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) is the chief copper mordanting principle for wool, and the only one that need be considered. Its principal use is in conjunction with iron and chromium compounds in the production of logwood blacks (which see). It is also used as a saddening or after-treating agent.

**Application of Dyestuffs to Mordanted Wool.** This will be discussed in detail under the head of Mordant Colors, but a few words at this point may not be out of place.

In general, the previously mordanted wool is introduced into a plain bath of the dyestuff, at, or a little above, ordinary temperatures; is brought slowly to a boil; and is dyed at a boil for one and one-half hours. In case the water used is hard, it should be corrected by the addition of a small amount of acetic acid.

**Application of Mordant and Dyestuff in same Bath.** This can be done successfully in only a few cases, and these will be referred to under their various heads. It is a very irrational method, and, ordinarily, nothing but failure can be expected.

**After-Mordanting.** Mention must be made of this third process, as it has recently developed into one of the most important mordanting methods for wool. It has always been used to some extent with logwood and the natural dyestuffs, and is known as the "stuffing" or "saddening" process; but during recent years a number of acid dyestuffs have been introduced which, with metallic mordants — particularly those of chromium — form color lakes that are practically of the same color as the dyestuff but are faster.

The process is simple, and usually consists in boiling the previously dyed material in a bath containing 1 to 3 per cent of potassium bichromate for one and one-half hours. A gradual dissociation of the  $K_2Cr_2O_7$  takes place; and the chromium, as an oxide, unites with the acid dyestuff to form a color lake in the body of the fiber, shades being produced which are often much faster than those of the original dyestuffs. This method does not apply to all of the acid dyestuffs, but only to a certain group which we shall designate as the **mordant acid dyestuffs**. The process is often spoken of as "after-treating" or "after-chroming."

**131. Mordanting of Silk.** Silk possesses even a greater affinity than wool for certain compounds, and among these are the oxides and hydroxides of the metals commonly used as mordants.

The absorbing character of silk, unlike that of wool, seems to be greater at moderately low temperatures, and from slightly basic rather than acid solution.

Cold and comparatively concentrated solutions of basic salts of chromium, aluminium, and iron, are best suited for silk mordanting. The silk is steeped in these solutions for a number of hours. Very little dissociation takes place in the concentrated bath, and the silk takes up the basic salt chiefly as such; but when the material is subsequently washed in a large volume of water, preferably running water, the dilution causes more dissociation, and the hydroxide of the metal is deposited in the fiber. Upon the final drying of the material, the hydroxides in most cases lose their water and become oxides.

The acid ions of the salt used are necessarily liberated during this process; but they are neutralized by passing the silk through an alkaline after-bath (usually of silicate or bicarbonate of soda), which completely fixes the mordant upon the fiber.

**132. Mordanting of Cotton.** The mordanting of cotton is rendered more complex and difficult of application than either that of wool or silk, since vegetable fibers have little if any natural attraction for metallic oxides or hydroxides, and of themselves seem to exert no decomposing or dissociating influence over mordanting principles.

So numerous and varied are the methods of applying mordants to cotton, that even a brief description of all the processes



and compounds that have been used and are being used at the present time, would make a volume by itself. We shall, therefore, confine ourselves to the methods of applying mordants, which are now largely depended on in the application of mordant colors to cotton. These may be enumerated under four heads:

1. The combined padding, ageing, and dunging processes.
2. The combined printing, ageing, and dunging processes.
3. Direct chemical precipitation upon the fiber.
4. Steam Printing.

Considered briefly, the principles of these are as follows:

FIRST METHOD.—*Padding, Ageing, and Dunging.* Certain metallic salts decompose at comparatively low temperatures when heated in a moist atmosphere. The acetates of aluminium and iron are the best examples of such compounds. These are readily soluble in water; and cotton material can easily be saturated with their solution, by the process called **padding**. Upon the cloth being dried, and heated for some time in a moist atmosphere, these salts decompose, forming basic acetates and, finally, hydroxides, with the liberation of free acetic acid, which, being volatile, is driven off by the high temperature and by the circulation of the air. The mordant is still further fixed upon the cloth, and any remaining acid neutralized, by the **dunging process**.

**Padding** consists in saturating the cloth by passing it, full width, through a bath of any given liquor; then working the liquor evenly and thoroughly into the cloth, and finally removing the excess by squeeze rolls.

After leaving the padding machine, the material is passed over drying cans or through a drying chamber and is ready for the "ageing."

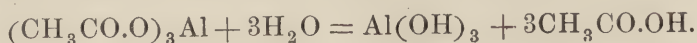
The **ageing** process was formerly carried out by heating the cloth for 48 hours, more or less, in a large, well-ventilated room heated with steam pipes and in which the atmosphere was kept moist by the admission of free steam. This method is used, to some extent at the present time; but in modern practice, steam ageing machines have largely replaced the older methods.

The steam ager consists of a long chamber containing two series of rolls, one at the bottom and one at the top, over which the cloth can be passed up and down, thus requiring several min-



utes for its passage through the machine. During this time the cloth is acted upon by steam at atmospheric pressure, a condition which brings about a rapid ageing, or decomposition of the mordanting principle. The cloth is then allowed to stand loosely piled, or hung, in a warm moist room for some time, when the process is completed.

Assuming that aluminium acetate is being used, then the complete ageing is represented by the following equation:



Intermediate reactions undoubtedly take place with the formation of various basic acetates; but when the process is efficient, most of the aluminium is finally deposited upon and in the fiber as the hydroxide.

The **Dunging** or **Fixing** consists in passing the cloth continuously through a bath containing some substance or substances capable of neutralizing any acid that has not been driven off during the ageing, and of completing the fixation of the mordant. Cow dung was formerly used almost exclusively for this purpose; hence the name "dunging." This substance contains a mixture of the phosphates, carbonates, silicates, and other salts of ammonium, potassium, sodium, and calcium, with certain fibrous and adhesive organic substances; and, when mixed with a small amount of precipitated chalk, makes a very effective neutralizing and fixing agent.

For convenience, modern methods have largely replaced the dung bath with baths of various substances and mixtures, such as sodium phosphate, ammonium carbonate, silicate of soda, and sodium arsenite; but it is held by many that the older method, although slower in action, gave better and more reliable results. The old name for the process has been commonly retained.

**SECOND METHOD.—Printing, Ageing and Dunging.** This process is similar to the first except that the mordanting principle (say acetate of aluminium) is made into a printing paste with various thickeners and is printed upon the cloth. Often a small amount of some inert color is added for the purpose of aiding the printer in his work. The material is then aged and dunged as above.

**THIRD METHOD.** This consists in padding the cloth with some mordanting principle, and then passing it through a bath containing some precipitant, or *vice versa*, that substance being used first which has the greatest affinity for the cotton, and which is the least likely to be flushed off upon passing into the second bath.

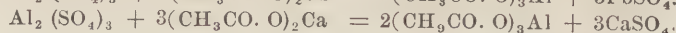
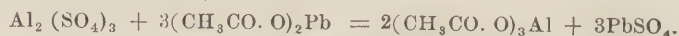
*Examples.* (a) Cotton cloth padded with sumac extract is passed through a bath of nitrate of iron or one of black liquor, the result being the precipitation of an insoluble tannate of iron upon the cloth.

(b) Cotton cloth padded with Turkey red oil is passed through a bath of basic aluminium sulphate, the result being the precipitation of an insoluble aluminium soap upon the cloth, which is useful as a mordant in Turkey red dyeing.

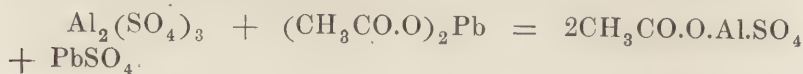
**FOURTH METHOD.—Steam Printing.** This consists in printing the dyestuff, together with the mordanting principle and the necessary thickener, upon the cloth; then drying and steaming. During the steaming process the color lake is developed directly upon and in the pores of the fiber. With the alizarines, it is quite essential that the cloth be given a preliminary preparation with Turkey red oil.

**Aluminium Mordants on Cotton.** The most important aluminium mordanting principles for cotton are aluminium acetate, aluminium sulphacetate, alum, aluminium sulphate, and the basic sulphates, sodium aluminate, and aluminium sulphocyanate. The nitrate, chloride, and chlorate are used to some extent in calico printing. As already explained, the aluminium mordanting principle should be free from iron.

*Aluminium acetate*  $[(CH_3CO.O)_3Al]$  may be prepared by dissolving  $Al(OH)_3$  in acetic acid, but more commonly by the double decomposition of aluminium sulphate with lead or calcium acetates; as follows:



By using less of the lead or calcium acetates, aluminium sulphacetate is formed as follows:





PRINTING MACHINE INSTALLED AT PACIFIC MILLS





Solutions of the aluminium acetates are known as **red liquor** since they are largely used as a mordanting principle in the production of Turkey reds.

*Alum and Aluminium sulphates* are seldom used as mordanting principles in the normal form; but the basic sulphates are frequently used, particularly in processes 1 and 3.

Normal *Aluminium sulphate*  $[\text{Al}_2(\text{SO}_4)_3]$  will not decompose even when boiled in dilute solution, but the basic aluminium sulphates decompose or dissociate readily. The basic sulphates, for this reason, are well suited for the ageing process.

*Sodium Aluminate*  $(\text{NaAlO}_2)$  comes in commerce usually in the lump or powdered form, and is soluble in water. For the production of "Turkey reds" on cotton the use of sodium aluminate as a mordanting principle has been found to reduce the susceptibility of the shade to the influence of iron and heat.

*Aluminium sulphocyanate*  $[\text{Al}(\text{CNS})_3]$  is used in the production of alizarine reds by steam printing, as it acts upon the steel doctor blades less than the other aluminium mordanting principles. The introduction of iron from this source is thus avoided, and the brilliancy of the prints correspondingly increased.

**Iron Mordants on Cotton.** The only important iron mordanting principles for cotton are ferrous sulphate, ferrous acetate, and ferric sulphate.

*Ferrous sulphate* [copperas,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ] is most commonly applied by the cloth being first padded with some tannin material, and then passed through a ferrous sulphate bath which acts as a precipitant, depositing an insoluble tannate of iron upon the material.

*Ferrous acetate*  $[(\text{CH}_3\text{CO.O})_2\text{Fe}]$  is the most important iron mordanting principle used with cotton. The crude ferrous acetate made by dissolving scrap iron in crude acetic acid or pyroligneous acid, is known as *pyrolignite of iron*. The chief use of the pyrolignite of iron is for the production of blacks, and for this reason it is called **black liquor**. It is also used with alizarine, producing purplish blacks when used alone and chocolate colors when in conjunction with aluminium mordants.

*Ferric sulphate*  $[\text{Fe}_2(\text{SO}_4)_3]$ , known in commerce as "Nitrate of Iron," is often used in cotton mordanting. The normal

salt is sometimes used, but more frequently the basic sulphate. The material is first padded with the ferric sulphate, and then passed through a bath of soda ash, lime water, or suspended chalk; or it is first impregnated with tannin, and then passed through the ferric sulphate.

**Chrome Mordants on Cotton.** The rapid increase in the use of chromium mordants has not been confined wholly to wool, for in recent years these mordants have received much favor in the printing, and to a less degree in the dyeing, of cotton with mordant colors. The chief chrome mordanting principles used with cotton are the chromium acetates and chromium bisulphite. Potassium bichromate is rarely used with cotton as a mordanting principle, but largely as an oxidizing agent in dyeing cotton with aniline black, cutch, and sulphur colors. Chrome alum is largely used in the preparation of chromium acetates and other chromium compounds used in cotton dyeing.

*Chromium acetates* are used in several forms but principally as the normal and basic salts. Normal chromium acetate has the formula  $(\text{CH}_3\text{CO.O})_3\text{Cr} + \text{H}_2\text{O}$ .

The basic chromium acetates  $(\text{CH}_3\text{CO.O})_2\text{Cr OH}$  and  $(\text{CH}_3\text{CO.O})\text{Cr} (\text{OH})_2$ , and intermediate acetates, are formed by adding sodium carbonate, caustic soda, or ammonia to a solution of the normal acetate. These acetates are commonly sold in solutions of about 32° Tw. The normal is green, and the basic violet in color.

*Chromium bisulphite*  $[\text{Cr}(\text{HSO}_3)_3]$  is best prepared by the action of sodium bisulphite with a chromium salt. The resulting solution is of a yellowish-green color.

It is necessary simply to pad the cloth with a hot solution of the chromium bisulphite, and then allow it to dry.

**Tin Mordants on Cotton.** Tin mordants are not so frequently used independently as in conjunction with aluminium and chromium mordants for brightening agents. The chief tin mordanting principles for cotton are stannic chloride and sodium stannate.

*Stannic chloride* or *Tin tetrachloride* ( $\text{SnCl}_4$ ) is used largely with the natural dyestuffs, being fixed upon the fiber by first treating with tannin and then working in a stannic chloride bath.

*Sodium stannate* ( $\text{Na}_2\text{SnO}_3$ ) is used for the natural dyestuffs,

and is found to work well with the eosins and certain azo colors. The material is impregnated with a solution of sodium stannate, and then passed through very dilute sulphuric acid or a solution of normal or basic aluminium sulphate.

**Copper Mordants on Cotton.** As a mordant, copper is not very important in cotton dyeing, and *Copper sulphate* is the only mordanting principle used. Its chief use is in the dyeing of cutch and logwood blacks, where it acts both as a mordanting principle and an oxidizing agent.

**Acid Mordants on Cotton.** The acid mordants of importance in cotton dyeing are tannic acid and related substances, and several of the fatty acids.

*Tannic acid* and *sumac extract* are both extensively used in the dyeing and printing of cotton with basic colors.

*Turkey red oil* (also known as soluble oil, sulphated oil, and olein) is also used for the above purposes.

## THE NATURAL ORGANIC DYESTUFFS.

**133. General Consideration.** Although for the most part superseded by the more modern artificial coloring matters, the natural dyestuffs hold an important place in history; and some of them, indeed, still have no equals in regard to certain characteristic properties that they may possess.

**134. Subdivision.** For convenience we shall subdivide the natural organic dyestuffs as follows:

1. Indigo, and related compounds.
2. Logwood.
3. Natural dyestuffs producing shades of a red character.
4. Natural dyestuffs producing shades of a yellow to brown character.

### INDIGO.

**135. General Consideration and Sources of Indigo.** For thousands of years, indigo has been the favorite blue dyestuff for both cotton and wool. It is said that textile material dyed with indigo has been found accompanying Egyptian mummies known to be at least 5,000 years old.

*Indigo blue* or *Indigotin* occurs in many plants, chiefly those of the genus *Indigofera*, the *Indigofera tinctoria* yielding the largest quantity. Among the other indigo producing plants, *Isatis*



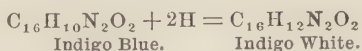
*tinctoria*, or *Woad* is the most important. This is still cultivated and used in the so-called "woad vat." The *Indigofera* thrive only in tropical climates; and the supply comes chiefly from the Bengal, Oude, and Madras Districts of India, and from Manila, Java, Japan, China, Central America, Brazil, and Africa.

*Artificial indigo*, a product of recent years, usually comes as a deep-blue paste, consisting approximately of 20 per cent indigo-tin and 80 per cent water.

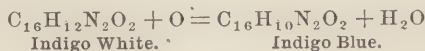
**136. Cultivation and Preparation of Natural Indigo.** Indigo cultivation is one of the chief industries in certain districts of India. The plant is of a herbaceous character, growing three or four feet high, with a stem about  $\frac{1}{4}$  inch in diameter.

Indigo blue does not exist as such in the plant, but is developed when the stems and leaves are steeped in water and allowed to ferment. A clear yellow liquid results, which contains the indigo as the soluble indigo white. Upon agitation and stirring, the oxygen of the air converts the indigo white into the insoluble indigo blue. This is allowed to settle, is pressed into cakes, and, when dry, is ready for the market.

**137. Chemistry of Indigo Coloring.** Unlike the majority of dyestuffs, indigo is insoluble in all the reagents that the dyer can employ practically; but nature has fortunately given it a property that renders its application comparatively simple. Upon reduction in an alkaline bath, it is readily converted into indigo white, as follows:



Upon even the mildest oxidation indigo white passes back to indigo blue, as follows:



Indigo white is readily soluble in water, especially in alkaline solution; and both animal and vegetable fibers absorb this solution with ease. Upon exposure of the saturated fiber to the air, the indigo white is oxidized almost immediately to the insoluble indigo blue, which is rapidly precipitated upon and in the pores of the fiber to as great a depth as the penetration of the indigo-white solution. The alkaline bath of indigo white is



commonly called an **indigo vat**; and the process of coloring is usually spoken of as **vat dyeing**.

**138. Application of Indigo.—Vat Dyeing.** There are at the present time three forms of indigo vats largely depended upon for indigo dyeing:

1. Fermentation Vats.
2. Zinc Lime Vats.
3. Hyposulphite or Hydrosulphite Vats.

The principle above mentioned (See Art. 137) is involved in them all, and they differ only in the method used to reduce the insoluble indigo blue to the soluble indigo white. In every case the vat must be alkaline, and this condition is usually maintained by means of lime or caustic soda. If the vat becomes in the least degree acid, the indigo white cannot be held in solution.

**139. Indigo Grinding.** In vat dyeing, the indigo must be in an extremely finely divided condition, otherwise the reduction is slow and incomplete. In the case of artificial indigo, which comes in the form of paste, the particles are sufficiently minute; but with natural indigo, a prolonged grind, often lasting two weeks, is necessary. The grinding is done in water, and is accomplished by allowing iron cannon balls or cylinders to roll over the indigo in iron drums.

**140. Fermentation Vats.** Previous to the 18th century, all indigo dyeing was done by means of fermentation vats. These are still largely depended upon in wool dyeing, but have been superseded in many places by hyposulphite vats. They are not used for cotton dyeing.

Of all the types of fermentation vat that have been used only the **Woad Vat** and the **Soda Vat** or **German Vat** are of sufficient importance to be mentioned.

The **woad vat** is the most important, and the one chiefly used at the present time. The following are the common ingredients. Different dyers have different ideas as to the quantity of each ingredient required; but the accompanying amounts may be considered approximately correct:

Woad (well broken).....	200 to 400 lbs.
Bran.....	20 to 30 lbs.
Madder.....	5 to 30 lbs.
Lime.....	20 to 25 lbs.
Indigo (thoroughly ground).....	10 to 20 lbs.
Contents.....	1,500 gallons.

Syrup and molasses are often added in place of bran, owing to the tendency of the latter to choke the vat. A portion of the lime may also be replaced with an equivalent of soda ash.

The vat having been made up as above, it is covered and allowed to stand over night. The cover is then removed and the contents examined. If fermentation has begun, there will be a slow but constant escape of bubbles of gas ( $\text{CO}_2$ ) at the surface; the bath will have a yellowish-green cast; and, upon gentle stirring, a coppery-blue scum will appear, and a sour but not disagreeable odor will arise. In most cases, decided fermentation sets in after thirty-six hours. It is well not to add all of the lime until the fermentation is well started; but on the other hand, the addition must not be delayed too long or decomposition will set in and the indigo be destroyed.

The process is controlled chiefly by the addition of lime and fermentation media. If the fermentation is too rapid, it may be reduced by adding lime; and if too slow, it may be increased by addition of bran, syrup or molasses. The result of too active fermentation is the wasting of indigo, and the final destruction or "blackening" of the vat, as it is called.

Experience alone can teach the requisite amount of lime to be added, and the time to add it. The vat should be ready for use on the third day.

The dyeing process is best carried out at a temperature of  $120^\circ$  to  $130^\circ$  F ( $50^\circ$  to  $55^\circ$  C). The scum must be removed from the top before the material is entered. Sometimes a large iron hoop covered with netting is lowered into the vat to keep the material away from the sediment at the bottom.

**Piece goods** are sewed into an endless band, well wet out, and are worked beneath the surface of the liquor by the process called **hawking**. This was formerly done by hand, but a **hawking machine** is now used, which consists of a pair of rubber-covered squeeze rolls located just below the surface of the vat and capable of keeping the cloth in constant motion. This process is continued until the cloth is thoroughly permeated with indigo-white solution (15 minutes to 2 hours), whereupon the cloth is passed between squeeze rolls and the color developed by immediate exposure to the air.

The use of too strong baths must be avoided or the goods will not be fast to rubbing. Two or even three dips in weaker baths will give the same depth of shade, and much faster and more even colors.

A thorough washing should follow the last dip of the dyeing.

**Loose wool** is commonly dyed in a circular vat, being introduced in nets. It is worked about by the process called **poling**, constant care being taken to keep it below the surface of the liquor. When the wool has become sufficiently permeated, the whole net is raised and allowed to drain; the excess of liquor is squeezed out; and the wool is then thrown in a loose pile on the floor and constantly worked over with a fork until it has become oxidized and the color developed. This takes at least fifteen minutes. The wool is then given another dip, or, if the color is deep enough, it is rinsed in a dilute acid bath, and then thoroughly washed.

The vat is fed at the close of each day's work by adding the necessary amounts of indigo and bran or syrup, lime being used to control fermentation. A fermentation vat cannot be used to advantage for more than six months.

**The Soda Vat or German Vat.** This is another form of fermentation vat, which, as its name indicates, is largely used in Germany. The *Badische Anilin and Soda Fabrik* recommend the following ingredients and quantities of each:

Syrup.....	8 lbs.
Bran.....	20 lbs.
Solvay Soda.....	14 lbs.
Lime.....	3 lbs.
Madder.....	6 lbs.
Indigo (20 per cent).....	12 lbs.

Contents 600 to 800 gallons.

It is reinforced with indigo, bran, syrup, lime, and soda.

The shades of blue are not as deep as, but are brighter than, those produced in the woad vat. This soda or German vat is useful in the production of light blues. Its application is the same as in the case of the woad vat.

**141. Inorganic Reduction Vats.** We shall now consider the three important vats of this class, first studying the chemistry and setting of each, and then their application as a whole.



The **ferrous sulphate vat**, also known as the **vitriol vat** or **copperas vat**, the oldest of the three, was first used during the 18th century, but has been almost entirely replaced by the zinc-lime vat and the hyposulphite vat. The ferrous sulphate vat is set as follows for 500 gallons of liquor:

Indigo (well ground).....	15 to 20 lbs.
Lime.....	30 to 40 lbs.
Ferrous Sulphate.....	30 to 50 lbs.

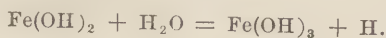
The customary practice is to first add the indigo and ferrous sulphate to vat, and then the lime gradually, as a milk of lime. This, however, is varied by some dyers. The vat is then well stirred, and is ready for use in 24 hours. From time to time it may be strengthened by addition of proper quantities of indigo, lime, and ferrous sulphate; but this form of vat does not remain in good condition more than three or four weeks, when it has to be thrown away.

The chemistry of the reaction in the ferrous sulphate bath is as follows:

The ferrous sulphate, reacting with calcium hydroxide (water-slaked lime), gives ferrous hydroxide and calcium sulphate:



Ferrous hydroxide, in the presence of water, passes into Ferric hydroxide, liberating nascent hydrogen:



The nascent hydrogen reduces the indigo blue to indigo white:



The **zinc lime vat**, also called **composition vat**, was introduced about the middle of the 19th century, and has ever since been used extensively for cotton dyeing. The zinc lime vat is set as follows:

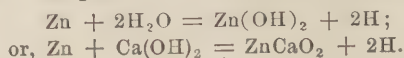
Water.....	500 gals.
Indigo.....	15 to 20 lbs.
Zinc Powder (Composition) .....	8 to 10 lbs.
Lime.....	20 to 25 lbs.

The well-ground indigo and zinc powder are added to the vat first and are well stirred; and then the lime, which has previously been slaked and made into a milk of lime, is slowly added. The vat is allowed to settle, and is then ready for use. Some dyers add the indigo and lime first, but the order of addition of ingredients makes but little difference. By adding the proper amount of indigo, lime, and zinc from time to time, the vat can be used for three or four months.



The chemistry of the reaction in the zinc-lime vat is as follows :

Zinc powder in the presence of an alkali will reduce water as follows:



The above equations represent the general reaction taking place, but the detail of the reaction is undoubtedly more complicated.

**The hyposulphite vat or hydrosulphite vat** is the most modern of the indigo vats. It is applicable in both cotton and wool dyeing, and its use is constantly increasing. In this vat the reduction is brought about by the action of a hyposulphite solution. This hyposulphite solution is sometimes sold in air-tight casks; but it keeps only a short time, and accordingly it is preferable for each dye house to manufacture its own hyposulphite. This chemical is ordinarily made by the action of zinc dust with sodium bisulphite at a low temperature. The process is as follows:

With 10 gallons of bisulphite of soda solution 72° Tw. mix 10 to 12 lbs. of zinc dust made into a paste, and slowly stir. Rise in temperature is prevented by the addition of ice, or the mixing may be done in a water-cooled iron vessel. In either case, enough cold water should be finally added to bring total volume to 19 gallons.

This mixture is well stirred for ½ hour, then allowed to stand for 1 hour, and finally there is slowly added, with gentle stirring, 10 lbs. of quicklime, which has been made into a milk of lime with 6 gallons of water and cooled. The stirring should continue ¼ hour after the lime has been added; and the whole mixture, which is now 25 gals., should be allowed to stand for two or three hours. The zinc settles out, and the hyposulphite solution remains above as a clear liquid. This is drawn off or filtered into air-tight casks or carboys, and must be kept from the action of the air until used. An addition of ¼ lb. to 1 lb. of caustic soda dissolved in a little water, will improve its keeping qualities.

The reduced indigo solution is prepared as follows:

75 lbs. Indigo Blue Artificial (20 per cent paste), or its equivalent in Natural Indigo.

10 gals. Boiling Water.

13 lbs. Caustic Soda made up to 8 or 9 gals. with water.

Heat mixture to 113°F or 45°C. Stir well, and allow to stand ½ hour; then add 25 gallons of the hyposulphite solution as previously prepared, stir well, and keep at 113°F or 45°C until the indigo has been completely reduced and has gone into solution. The addition of a little hyposulphite solution (1 to 2 gallons) from time to time will aid in the solution of the indigo. When the reduction is completed, a little of the solution carefully drawn with a pipette

and allowed to run on to a filter paper, will develop a decided blue in less than 30 seconds.

The vat is set as follows :

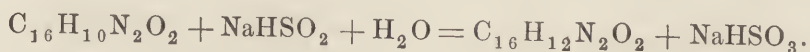
For 500 gallons capacity, add 400 gallons of water heated to 20°C or 68° F, and 1 gallon of hyposulphite solution, and allow to stand over night.

In the morning the necessary amount of reduced indigo is added, by means of a funnel with a stem long enough to reach to the bottom of the vat. For a full-strength vat add 25 gallons of the reduced indigo prepared as above; stir gently; and allow to stand quietly for an hour, when the vat is ready for use.

The reduced indigo should be kept on hand and added to bath as is necessary.

This vat is applicable to both cotton and wool material. In the case of cotton it is commonly used cold; but for very heavy material, such as duck or canvas, better penetration is secured if the vat is heated to 120°F.

Our knowledge in regard to the chemistry of the hyposulphite vat is somewhat uncertain, but it is known that powdered zinc reacting with sodium bisulphite ( $\text{NaHSO}_3$ ) gives rise to the acid sodium salt of hyposulphurous acid. To this the formula  $\text{NaHSO}_2$  is most commonly assigned. It reacts with indigo as follows :



The application of the hyposulphite vat to wool is similar in manipulation to that of the fermentation vat already described; and the dyeing is carried on at a raised temperature, usually about 120° F.

**142. Application of Indigo to Cotton.** The principle of the application of indigo to cotton is practically the same with all vats. Deep rectangular vats are commonly used, which contain two sets of horizontal rolls, one located at the top just below the surface of the liquor, and the other set several feet below, but far enough from the bottom to avoid disturbing the sediment.

The general form of apparatus will be understood from Fig. 59. The cloth enters at A, and rollers over which it passes are so arranged that it does not again come in contact with the air until it leaves the vat at B. It immediately passes between squeeze rolls, and then travels through the air several minutes, by passage

about a second set of rolls, usually located above the vat to economize room. It is while passing through the air that the indigo white becomes oxidized, and the color developed. If a deeper

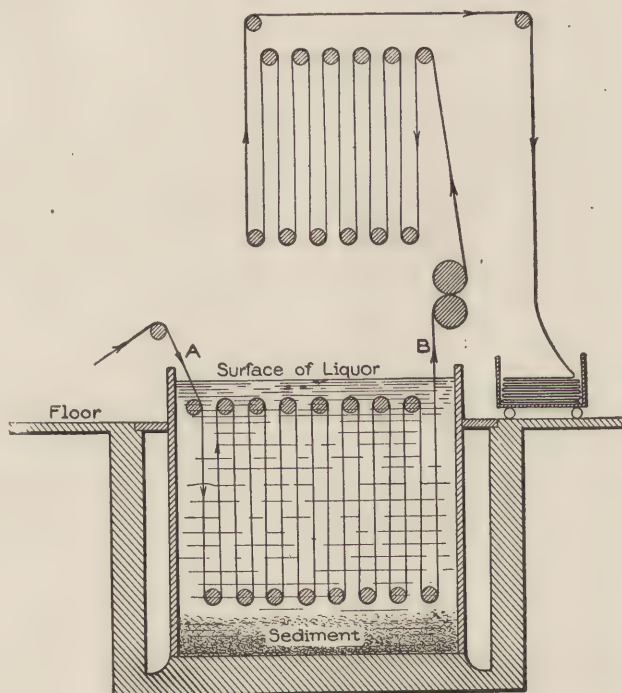


Fig. 59.

shade is desired the cloth may be run through a second or even a third vat, or may be piled up and run through the first vat a second time.

**143. Indigo Extracts.** These are prepared by the action of concentrated sulphuric acid upon indigo blue, the reaction giving rise to the sulphonic acid derivatives of indigotin, which are soluble in water and which have the property of easily dyeing wool from an acid solution. They have been and are still used in wool dyeing, giving brighter shades of blue than can be produced in the indigo vat; but whereas vat indigo blue is one of the fastest colors known, the extract blue is fugitive to both light and alkalis.



## LOGWOOD.

**144. Source of Logwood.** Logwood is the product of a large tree of rapid growth known botanically as the *Hæmatoxylon Campechianum*. It is a native of Central America and the adjacent islands, Jamaica being the chief center of the industry at present. Raw logwood, as its name indicates, comes in the form of rough logs. These are ground, or rasped, into small chips, and may be used in this form or as water extracts.

**145. Chemistry of Logwood Coloring.** By carefully extracting freshly cut logwood, there can be obtained a yellowish-white crystalline compound having the formula  $C_{16}H_{14}O_6$ , and known as *hæmatoxylin*.

When exposed to the air, hæmatoxylin, especially in the presence of an alkali, rapidly oxidizes to a reddish-brown substance called *hæmatein*, which has the formula  $C_{16}H_{12}O_6$ . This is the active coloring matter of logwood. Upon further oxidation, hæmatein passes into a brown, resinous body which is of no value for coloring purposes.

Hæmatein has the property of uniting with various metals to form salt-like compounds that possess decided colors. For instance, when we add sodium hydroxide (NaOH) to a solution of hæmatein, we get the sodium compound of hæmatein, which possesses a deep reddish-violet color, but which, being very soluble in water, cannot be satisfactorily attached to textile material. With such metals as chromium, iron, aluminium, and copper, however, hæmatein forms insoluble colored compounds, or color lakes, which, by using certain of the soluble compounds of these metals as mordanting principles, can be fixed upon the fiber by various methods. Logwood is an adjective color in every sense of the word. It is also polygenetic, but the range of shades is limited between blue and black, and black and gray.

**146. Logwood Ageing.** Ordinarily a sample of logwood is most efficient when all of the hæmatoxylin has been oxidized or developed to hæmatein, but with none of the latter over-oxidized to the brown, resinous product. This ideal condition can never be exactly attained, and even the best samples of logwood will contain both hæmatoxylin and hæmatein. With this in view, logwood is commonly subjected to an ageing or curing process. This



condition may also be brought about, to a certain extent, in the dye bath, by the addition of a small amount of some oxidizing agent or by the use of an oxidizing mordant.

Logwood chips are commonly aged as follows:

After having been made into a large pile several feet in depth, the chips are well moistened with water, and then worked over with wooden shovels, every portion of the pile being thus brought in contact with the air. This is continued for a period of from three to four days to two weeks, depending largely upon atmospheric conditions. After some experience, one can tell, from the appearance of the chips, when the right stage of oxidation is reached. The chips are then stored in such a way that they will be exposed as little as possible to the oxidizing influence of the air.

**147. Logwood Liquor.** Logwood liquor is a decoction of logwood made by extracting aged logwood chips with water. It usually stands at about 15° Tw., and is freshly made as needed, as it does not keep well. Sometimes the extraction is done in the dye bath, previous to the dyeing, by entering the logwood chips in bags, and boiling several hours, but more frequently by extracting the chips in a separate boiler at a temperature of from 60° to 80°F.

**148. Logwood Extracts.** These are the commonest commercial forms of logwood at the present time. They are made by two methods:

- (1) Extracting the logwood at boiling temperature with pure water.
- (2) Extracting under steam pressure of 20 to 30 lbs. per square inch.

In either case the resulting logwood liquor, which has a specific gravity of 15° Tw., is concentrated in vacuum pans until it reaches a gravity of about 50° Tw., when it is known as the "liquid" extract; or it may be evaporated to dryness, giving the "solid" extract.

**149. Application of Logwood to Wool.** Logwood is extensively used for the production of cheap blacks on wool. There are three general methods of application:

(1) **CHROME BLACKS:** If logwood is well aged, either of the mordanting methods C and D (see Article 130) will give excellent results. If the logwood is unaged, method B is the best. With a straight chromium mordant, blue shades are produced. To overcome this, a small amount of some yellow dyestuff, as fustic or alizarine yellow, and a very little of a mordant red, are added to

the dye bath along with the logwood, the result being a dead black.

For 100 lbs. of wool mordanted by methods B, C, D, or E, prepare the dye bath with

40 lbs. Logwood Chips, or equivalent in Extract.  
4 lbs. Fustic.  
 $\frac{1}{2}$  lb. Alizarine.

Enter at 100°F; bring slowly to a boil; and dye at a boil for  $1\frac{1}{2}$  hours. For cheap blacks the alizarines may be omitted.

In order to produce a dead black instead of a blue, copper sulphate ( $\text{CuSO}_4$ ) is often used as a mordanting principle in connection with potassium bichromate, sulphuric acid being used as a mordanting assistant.

(2) IRON BLACKS. These are the oldest forms of logwood blacks. Ferrous sulphate and copper sulphate are the mordanting principles used. The following may be taken as a representative dyeing process:

For 100 lbs. of wool:

Mordant in a bath containing  
8 to 12 lbs. Ferrous sulphate (copperas).  
3 to 4 lbs. Copper sulphate.  
6 to 8 lbs. Tartar.

Enter at 140°F; bring slowly to a boil; and mordant at a boiling temperature for one hour. Then dye in a bath made up with

50 to 80 lbs. logwood Chips, or equivalent in Extract.  
3 to 5 lbs. Fustic.

Enter at 100°F, and dye at a boil  $1\frac{1}{2}$  hours.

Iron blacks are produced also by the stuffing or saddening method (see Article 129-3). This is accomplished by first boiling the wool for one and one-half hours, in a bath made up with plain logwood (say, the equivalent of 50 to 80 lbs. of logwood chips) and fustic (say, 4 to 6 lbs. per 100 lbs. of wool). The material is then raised, and 5 to 7 lbs. of ferrous sulphate and 2 to 3 lbs. of copper sulphate added, and boiling continued  $\frac{3}{4}$  to 1 hour.

(3) ONE-DIP BLACK. This is accomplished by using the logwood and mordanting principle in the same bath, and adding enough of some acid (usually oxalic) to prevent the precipitation of the color lake. The following gives good results:

For 100 lbs. of wool:

50 lbs. of Logwood Chips, or equivalent in Extract.

4 to 6 lbs. of Ferrous sulphate.

1 to 2 lbs. of Copper sulphate.

2 to 2½ lbs. of Oxalic acid.

The bath is first boiled for a few minutes, then cooled a little; the material added, and boiling continued from 1 hour to 1½ hours.

**150. Application of Logwood upon Cotton.** The use of logwood in cotton dyeing has greatly declined during recent years, particularly for printing and piece dyeing, owing to the introduction of aniline black, and the direct cotton and sulphur blacks. Logwood is still largely used, however, in dyeing cotton warps, and to a less extent in dyeing loose cotton. It is applied chiefly upon an iron tannin mordant, and the following will serve as a representative process:

(1st) Saturate the material with sumac solution at 150°F — if cloth, in a jig dyer; if warp, in a chain dyer; and if skeins, by hand — using 10 to 20 lbs. sumac extract (depending upon quality) per 100 lbs. cotton. Work well in this sumac solution; then allow to steep 12 hours, or over night, in the slowly cooling bath; and then wring or squeeze well, but do not wash.

(2d) Work in an iron bath of either the pyrolignite or the so-called nitrate of iron, which should stand at 5° Tw.

(3d) Work in a weak bath of milk of lime  $\text{Ca}(\text{OH})_2$ , and after rinsing, the material is ready for the dyeing process.

(4th) DYEING. For every 100 lbs. of material, the dye bath is made up with

10 lbs. Logwood Extract.

1 lb. Fustic Extract.

Enter cold; bring slowly to boil; and dye at a boil until the black is fully developed, not less than 1 hour. To render the color faster, 1 to 2 lbs. of copper sulphate may be added to the dye bath, when the dyeing is about two-thirds completed. A final soaping gives the black a brighter appearance, and softens the "feel" of the material.

One-dip blacks are often used on loose cotton. The process consists in boiling the cotton in a bath made up as follows:

Necessary amount of Logwood.

6 lbs. Copper acetate,

4 lbs. Copper sulphate,

or

4 lbs. Soda ash.

Enter cold; bring slowly to boil; and dye at a boil for 1 hour. Lift the cotton, and expose to the air several hours. If not dark enough, repeat the process.

**151. Application of Logwood upon Silk.** Logwood is extensively used for the production of black upon silk. Iron mordants are almost exclusively used for this purpose, and tin mordants less often. The other metallic mordants are here of little or no value.

The process usually consists in treating the silk alternately with some tannin material and the nitrate of iron, until the silk is thoroughly filled with a tannate of iron. It is then dyed in a logwood bath. In this way the weight of the silk greatly increases, sometimes 3 or 4 times its original weight.

### RED NATURAL DYESTUFFS.

**152. Soluble Redwoods.** These include Brazil wood, peach wood, sapan wood, and Lima wood. They all contain the same coloring principle *brazilin*, which is soluble and easily extracted by water. Upon oxidation brazilin passes into *brazilein*, which is the active coloring matter. These dyewoods are adjective, and also polygenetic, producing the following colors:

With Aluminium mordant.....	Red.
With Chromium mordant .....	Violet to Claret Red.
With Iron mordant .....	Violet to Purple.
With Tin mordant.....	Crimson Red.

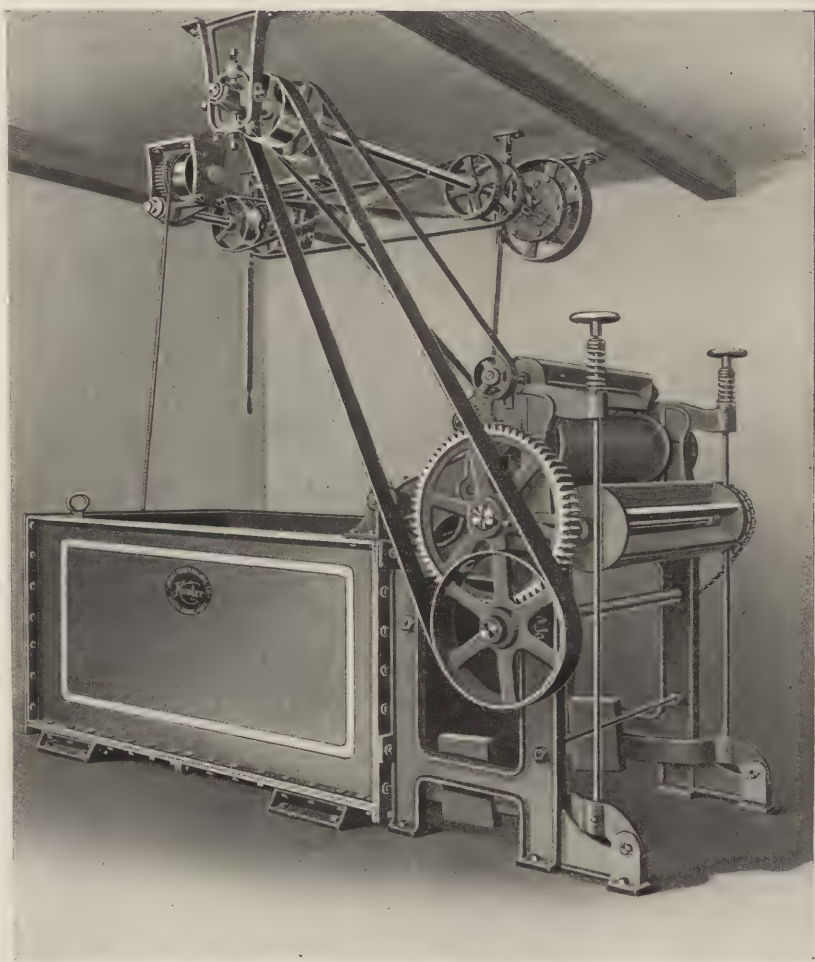
They may be applied to mordanted cotton or wool by boiling in a plain bath of the extracted color. (For methods of mordanting see Articles 130 and 132.)

**153. Insoluble Redwoods.** These include bar wood, saunders wood, and cam wood. They are much harder and closer-grained than the soluble redwoods, and their coloring principle, known as *santalin*, is practically insoluble in water. For this reason, extracts cannot be prepared, and the chips have to be added directly to the dye bath. They are adjective, and also polygenetic, producing the following colors:

With Aluminium mordant.....	Red to Brownish Red.
With Chromium mordant.....	Purplish to Reddish Brown.
With Iron mordant.....	Violet to Purplish Brown.
With Tin mordant .....	Red to Brown Shades.

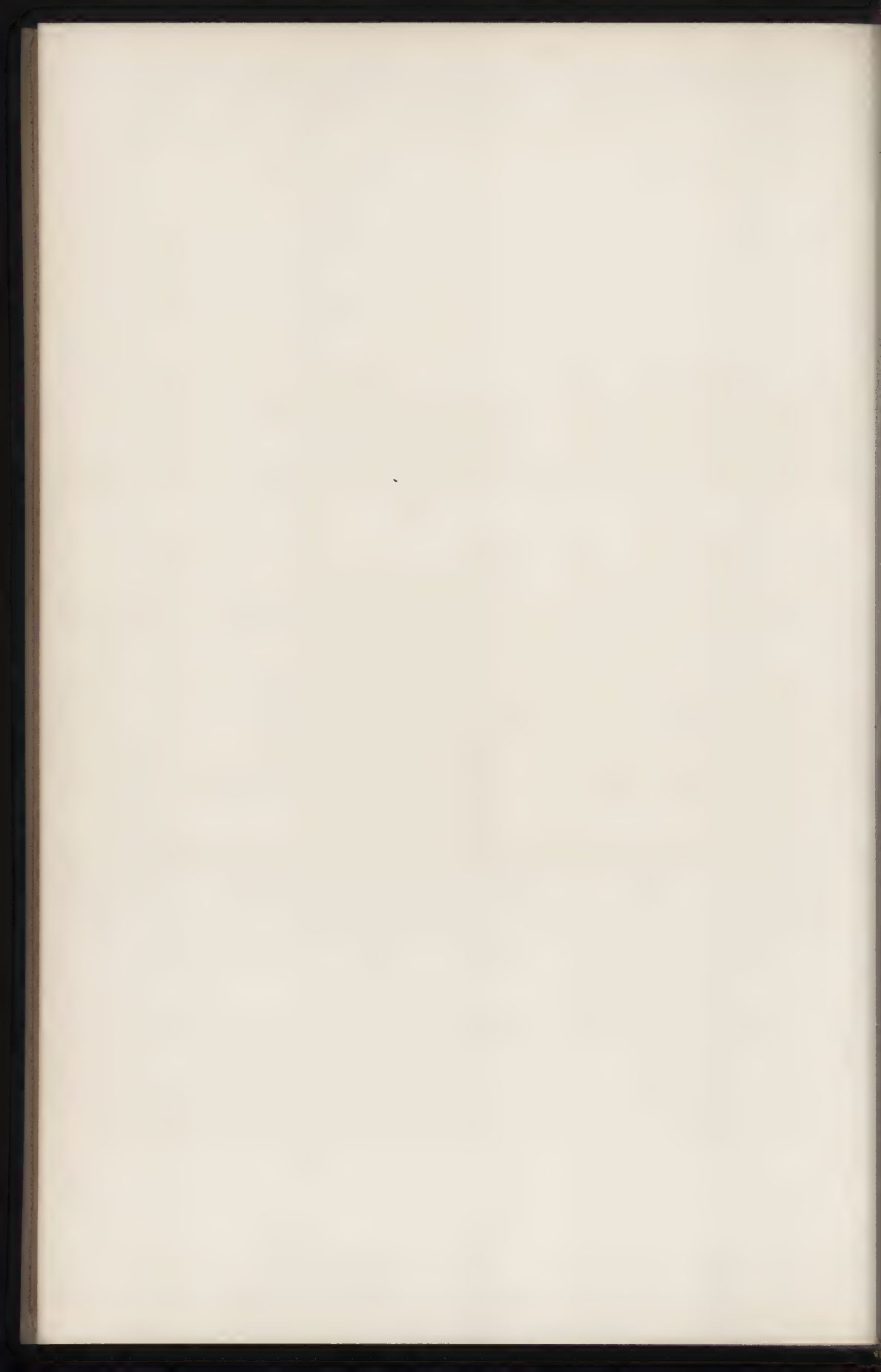
They may be applied to mordanted wool and cotton, by boiling the material for a long time in a dye bath containing the ground





**INDIGO DYEING MACHINE**

James Hunter Machine Co



or chipped wood. They are more valuable for the production of compound shades, with logwood, madder, fustic, and other natural dyestuffs, than as self colors.

None of the redwoods can be considered fast to light; but the colors produced with the insoluble dyewoods stand milling very well. The redwoods are very seldom used at the present time, artificial dyestuffs having been introduced, which give faster shades at lower cost.

**154. Madder.** This is prepared from the root of a plant known botanically as *Rubia tinctorium*, which is native to Asia Minor. It was known to the ancients, and was always used by the old school of dyers for the production of fast reds upon both wool and cotton. It is adjective and polygenetic, giving shades as follows:

With Aluminium mordants.....	Bright Reds and Pinks (Turkey Red).
With Chromium mordants .....	Wine Color, Claret Reds.
With Iron mordants .....	Violet Black.
With Tin mordants .....	Reddish Orange.

*Alizarine* ( $C_{14}H_8O_4$ ) is the principal constituent and active coloring agent of madder, *Purpurin* ( $C_{14}H_8O_5$ ) occurring in smaller quantities.

In 1868, Grabe and Liebermann discovered the process of manufacturing alizarine. The artificial product, being cheaper and more even and reliable in quality, has replaced madder entirely in dyeing and printing, except in Oriental countries where it is native. It is still used to some extent in the setting of fermentation indigo vats. Alizarine is used largely in steam calico printing, for the production of Turkey reds on cotton with an aluminium mordant, and in wool dyeing.

**155. Cochineal.** This red coloring matter is obtained from the dried body of an insect which is native to Mexico and Central America. The insect lives upon certain kinds of cactus plants. The coloring principle of cochineal is *Carminic acid* ( $C_{17}H_{18}O_{10}$ ), which is soluble in water, and which has the property of forming bright color lakes with metals as follows:

With Tin mordants .....	Scarlet.
With Aluminium mordants .....	Crimson.
With Chromium mordants .....	Purple.
With Iron mordants.....	Purple.

The principal uses of cochineal have been for the production of scarlets and crimsons on wool, aluminium and tin mordants being the most important for these purposes. The mordant may be applied previous to the dyeing, or at the same time. The latter method is the commoner in practice, and the following process gives excellent results:

For 100 lbs. wool:

10 to 20 lbs. Cochineal.

4 lbs. Oxalic acid.

2 lbs. Tartar.

Add last 6 lbs. *Stannous chloride*. Boil bath 5 or 10 minutes, then cool to 160° F. Enter wool, bring slowly to a boil, and dye at a boil for  $\frac{3}{4}$  hour. To increase the fiery character of the scarlet, a little yellow dyestuff should be added.

The acid scarlets (artificial colors) have now superseded cochineal to a great extent.

**156. Kermes and Lac Dye.** These are two more red coloring matters of similar origin to cochineal, but of less importance.

**157. Orchil and Cudbear.** Two coloring matters derived from certain rock mosses, which give bluish-red colors on wool and silk.

### YELLOW NATURAL DYESTUFFS.

**158.** Under this head are commonly included a number of vegetable coloring matters that give shades varying between yellow and brown. The following are the most important: Fustic, Quercitron Bark, Persian Berries, Turmeric, Weld, and Cutch. These have for the most part been replaced by the artificial dyestuffs.

**159. Fustic or Cuba wood** is sold either as ground wood, or in the extract form. It is a mordant color, and is still used in wool dyeing, chiefly in combination with logwood; and for the production of compound shades, with indigo and the alizarine colors.

**160. Quercitron Bark** comes from a species of oak, growing in the middle and southern states. It is sold either as the ground bark or in the form of extract. It is a mordant color, and gives brighter shades than fustic. It is used to some extent in wool, cotton and silk dyeing, both as a self-color and in the production of compound shades.



**161. Weld** is an herbaceous plant grown in Europe. It dyes wool and silk a bright yellow color, but is seldom used at the present time.

**162. Persian Berries.** A name applied to the berries of the buckthorn. Usually sold as an extract. Its principal use at the present time is in steam calico printing.

**163. Turmeric** is the ground root of a plant that grows in Asia. It possesses the characteristic of being a substantive or direct dye for cotton, wool, and silk. It gives bright shades of yellow, but they are fugitive to light and washing. Its chief use at the present time is as an adulterant for mustard.

**164. Cutch or Gambia** is the extract of the nuts and tender portions of various forms of acacia trees growing chiefly in India. It is largely used for the production of browns on cotton. The process is as follows :

For 100 lbs. of cotton :

Boil the material for one hour in a bath made up with

10 lbs. Cutch.

1 lb. Copper sulphate.

Allow it to remain in the cooling dye bath for several hours. Develop color by working  $\frac{1}{2}$  hour in a hot bath at 180° F, containing

2 to 3 lbs. Potassium bichromate.

The shade may be varied by diminishing or increasing the amount of cutch used, and the copper sulphate in the same proportion.

Cutch is very largely used for the production of fast tan shades upon cotton warps and hosiery. It may be applied to wool by the same process as for cotton, but is little used for this purpose. It is used in silk dyeing, where it acts as a tannin material, assisting in holding the iron upon the fiber.



FARBWERKE VORM. MEISTER LUCIUS & BRÜNING, HOECHST a. M.

# TEXTILE CHEMISTRY AND DYEING.

## PART IV.

### ARTIFICIAL DYESTUFFS.

**165.** Dyers of the olden times depended almost entirely upon the so-called natural dyestuffs, of which the number of useful ones was limited. In those days the young dyer was seriously handicapped in his search for information, for the dealers in these natural dyestuffs knew little, if anything, about their application, and as there were no publications on the subject, the young man's only source of information was from older dyers.

A decided change took place between the years 1856-1860, when it was discovered that coloring matters, which surpassed any of the natural dyestuffs in brilliancy, could be manufactured from the products of the distillation of coal tar. Many of these so-called coal-tar colors were discovered and put upon the market, and, as the manufacturers knew more about their application than the dyers, it was to the advantage of the former to circulate this information. As a result, the dyestuff manufacturers published sample cards and books containing dyed samples and the necessary information for the successful application of their colors. At the present time enormous sums are spent every year by them in the investigation and publication of the best methods of applying the colors they place upon the market.

In more recent years numerous books have been published on the various branches of textile coloring; this, with the establishment of textile schools, makes it possible for bright young men to become expert dyers, without assistance from friendly dyers.

**166. Classification of Artificial Dyestuffs.** For the practical dyer there is but one satisfactory method of classifying the artificial coloring matters, *i.e.*, according to their action upon the

different fibers; in other words, according to their application. Therefore, in our study of them we shall consider the following classification:

- (1) Basic colors.
- (2) The Eosins and related Dyestuffs, known as the Phthalic Anhydride Colors.
- (3) Acid Colors.
- (4) Direct Cotton Colors.
- (5) Sulphur Colors.
- (6) Mordant Colors.
- (7) Mordant Acid Colors.
- (8) Insoluble Azo or Ingrain Colors.
- (9) Reduction Vat Colors.
- (10) Aniline Black.

#### BASIC COLORS.

167. The basic colors were the earliest of the so-called artificial dyestuffs or coal-tar coloring matters. They belong to that class of compounds known as the *substituted ammonias* or *amines*, *i.e.*, they are derived from ammonia ( $\text{NH}_3$ ) by the replacement of one or more hydrogen atoms of one or more molecules of ammonia with various other elements, or groups of elements. These substituted ammonias, like ammonia, are basic in character, and, like all bases, have the power of neutralizing acids. It is for these reasons that this class of dyestuffs is designated as the *basic colors*. It is only when the color bases, *i.e.*, the substituted ammonia compounds, from which the coloring matters are derived, are neutralized with acids that their coloring power is fully developed.

A study of the *properties and composition of wool* indicates that it is of a weakly acid character, and its acid properties seem to be sufficient to cause it to unite with these color bases and develop their characteristic colors. For this reason wool may be dyed directly with the basic colors.

With cotton it is different, for this fiber apparently has no acid character and cannot combine directly with these color bases. Therefore, the basic dyestuffs have no direct affinity for cotton, and cannot be applied to this fiber except by the aid of some assisting acid substance. Tannic acid is most frequently used for this purpose, and acts as an acid mordant. (See No. 132.)



**168. Application of Basic Colors to Wool.** Although the basic colors have a direct affinity for wool, they are not extensively used in wool-dyeing, because there are, in most cases, acid colors (see No. 180), which will not only give the same color but possess greater fastness.

The following process is well adapted to the dyeing of wool with the basic colors.

For 100 pounds of wool material prepare the dye bath with:

1 to 2 lbs. Color.

$\frac{1}{2}$  lb. Acetic Acid (to counteract hardness of water).

10 lbs. Glauber's Salt.

Enter the material at 180° F. and dye at a boiling temperature for forty-five minutes to one hour, then wash and dry.

**169. Application of Basic Colors to Silk.** The basic colors dye silk directly and are extensively used with this fiber when bright, rather than fast colors are desired.

The process most frequently used is as follows:

Prepare the dye bath with:

10 gallons "Boiled Off Liquor".\*

30 gallons Water.

Sufficient Sulphuric, Acetic, or Tartaric Acid to render the bath slightly acid.

Enter silk at 100° to 110° F., work for a few minutes at this temperature, then raise the silk from the bath and add the necessary amount of dyestuff (previously dissolved in water). Re-enter the silk, turn several times, raise the temperature of the bath to 140° F. and finally bring to a boil. It is best to raise the silk from the bath each time the temperature is raised. With colors that go on evenly at lower temperatures it is advisable not to bring the bath to the boiling point.

With some basic dyestuffs a neutral or slightly alkaline bath of boiled off liquor is preferable.

**170. Application of the Basic Colors to Cotton.** It is in the dyeing and printing of cotton material that the basic colors find the widest application. The cotton, whether it be in the form of piece goods, yarn, or loose cotton, must first be impregnated with tannic acid in some form, and the tannic acid then fixed upon the material as an insoluble metallic tannate (usually of antimony).

\*NOTE.—Preliminary to dyeing, silk is subjected to the so-called "boiling-off" or degumming process. This consists in boiling the silk in a solution of potash soap, sometimes made slightly alkaline with a little soda ash or borax, for one-half hour more or less. As a result the sericin is dissolved and the fibroin or true silk fiber remains. The solution of sericin is known as "boiled off liquor" and is extensively used in silk-dyeing.

When thus mordanted the cotton is ready for dyeing, which is carried out in a bath containing the basic color.

Process for 100 lbs. of cotton yarn.

Prepare the tannin bath with

125 to 150 gallons Water.

$2\frac{1}{2}$  to 5 lbs. Tannic Acid;

or

5 to 10 lbs. Light Shumac Extract.

Raise the temperature of the bath to 180° F., enter yarn, work it at this temperature for one-half hour, then allow it to stand in the slowly cooling bath (entirely covered with the liquor) for two hours when light colors are to be produced, and over night for heavy colors. The yarn is then wrung and hydro-extracted without washing, then worked for one-half hour in a cold bath containing 1 to 2 lbs. tartar emetic or equivalent of some other antimony compound, and finally washed thoroughly.

The above treatment fixes an insoluble tannate upon the fiber.

The yarn is then dyed in a bath made up as follows:

175 to 200 gallons Water.

1 to 3 lbs. Acetic Acid (to correct hardness of water).

2 lbs. Basic Color. For full shade.

Begin the dyeing cold and bring the temperature to from 120° to 130° F. before the dyeing is completed. With a few colors, *e.g.*, Methylene Blue the temperature may be raised as high as 160° F., but a higher temperature than this is seldom beneficial. The addition of one or two pounds of alum to the dye bath, before the introduction of the dyestuff, is advisable with colors which have been found to dye unevenly, and in every case the dyestuff should be added to the bath in several portions rather than all at one time.

In the *dyeing of cotton piece goods*, the principles of the process are identical with those of yarn dyeing. A series of three Jig Dyeing Machines\* is best adapted for this purpose, the first for the tannin bath, the second for the antimony compound, and the third for the dyestuff. Padding machines are sometimes used for the first two operations.

**171. Characteristic Properties of the Basic Colors.** The basic colors are characterized by their great brilliancy and high tinctorial or coloring power; 2 per cent of a basic color commonly producing as great a depth of shade as 3 to 5 per cent of an acid color or a direct cotton color. Their solubility in water is not as great as that of the direct cotton and acid colors, and a few of them, known as spirit soluble colors, are so insoluble in water that alcohol has to be used as a solvent. Their fastness to light is by

\*A jig dyeing machine is illustrated in Fig. 69. It consists of a dye vat and two rolls, so arranged that several hundred yards of cloth may be passed full width from one roll through the liquor in the vat, and wound upon the other roll. The cloth is thus passed back and forth until thoroughly permeated with the liquor contained in the vat.

no means satisfactory, but their fastness to washing and soaping is excellent (except the reds), and for this reason they are extensively used in calico printing and in the dyeing of cotton yarn for gingham.

**172. Important Basic Colors.** The following is a list of some of the more important basic colors:

REDS.

Acridine Red.  
Magenta.  
Rhoduline Red.  
Rosaniline.  
Rhodamine (see phthalic anhydride colors).  
Saffranine.

BLUES.

Basle Blue.  
Diazine Blue.  
Diphenes Blue.  
Indamine Blue.  
Indazine Blue.  
Iondoin Blue.  
Indophenin Blue.  
Metamine Blue.  
Metaphenylenes Blue.  
Methylene Blue.  
New Blue.  
Night Blue.  
Nile Blue.  
Victoria Blue.

GREENS.

Benzal Green.  
Capri Green.  
China Green.  
Emerald Green.  
Ethyl Green.  
Malachite Green.  
Methyl Green.  
Methylene Green.  
New Green.  
Solid Green.  
Victoria Green.

## ORANGES AND YELLOWS

Acridine Orange.  
Auramine.  
Azophosphine.  
Chrysoidine.  
Flavindulin.  
New Phosphine.  
Phosphine.  
Tannin Orange.  
Thioflavine T.

VIOLETS.

Cresyl Fast Violet.  
Crystal Violet.  
Hoffmans Violet.  
Methyl Violet.  
Tannin Heliotrope.

## BROWNS.

Aniline Brown.  
Bismark Brown.  
Diazine Brown.  
Leather Brown.  
Manchester Brown.  
Tannin Brown.

## BLACKS AND GRAYS

Diazine Black.  
Methylene Black.  
New Gray.  
Nigramine.  
Nigrosine.

**173. The Janus Colors.** The *janus colors*, although often classed as basic colors, constitute a group by themselves. Their molecular structure is such that they contain simultaneously the characteristic groups of both the acid and basic colors. They possess the peculiar property of *dyeing both cotton and wool* directly in an acid bath. Like basic dyestuffs they may also be applied to tannin mordanted cotton. They are useful in the dyeing of cotton and wool union goods.

### THE PHTHALIC ANHYDRIDE COLORS.

174. This group includes a few dyestuffs such as the eosins and rhodamines, which produce very brilliant red dyeings, and are largely used for the production of bright pinks. They resemble

the basic colors in certain respects, and the acid colors in others, but differ sufficiently from both to be placed in a class by themselves. The colors of this group, certain rhodamines excepted, are all related to phthalic anhydride, and it is from this fact that they derive their name. They are *used chiefly in wool and silk dyeing*, and to a limited extent in cotton dyeing. The rhodamines resemble the basic colors both in composition and properties, and are frequently used in calico printing.

**175. Application to Wool.** With the exception of the rhodamines, the colors of the phthalic anhydride group are best applied to wool in a bath containing tartar (potassium bitartrate), alum, and acetic or sulphuric acids.

The dye bath is made up as follows:

Necessary amount of color.

\* 2 per cent Potassium Bitartrate (Tartar).

2 per cent Alum.

1 to 2 per cent Acetic Acid.

Enter material at 40° C, raise the temperature gradually to 100° C, and dye at a boil for one-half hour.

With the rhodamines the following gives better results:

Necessary amount of color.

15 to 20 per cent Glauber's Salts.

1 to 5 per cent Sodium Bisulphate.

The rhodamines are often used in shading other colors.

**176. Application to Silk.** The colors of this group are often used for silk dyeing on account of their great brilliancy. The method of application is the same as that already given for basic colors. (See No. 169.) They may also be applied in a bath acidified with acetic acid, without any addition of boiled off liquor or soap. In most cases the color is taken up by the silk at a temperature of 120° to 140° F., and the bath need not be raised above that temperature.

**177. Application to Cotton.** Cotton may be dyed directly with the colors of this group in a concentrated bath of common salt, with or without the addition of 1 per cent alum, but the dyeings are so fugitive to washing and light that they are applied in

\* NOTE.—In all recipes, percentages refer to weight of goods being dyed, unless otherwise stated. Thus 2 per cent of potassium bitartrate means two pounds of this compound to every 100 lbs. of material being dyed.



this way only when the material is not to be subjected to washing or much light. If the cotton is previously mordanted with Turkey-red oil or aluminium the dyeings are faster.

The following process is commonly used:

First work the material in a bath made up as follows:

1 part Turkey-red Oil.

2 parts Water.

Wring or squeeze thoroughly and repeat the operation several times, then dry at a moderate heat or steam under 5 lbs. pressure for 20 to 30 minutes. If extremely level and deep shades are desired, this operation must be repeated two, or even three times. The material is then dyed in a short, cold bath containing the necessary amount of dyestuff.

When *aluminium* is used as the mordanting metal the process is as follows:

The material is worked in a bath containing

1 part Turkey-red Oil;

8 parts Water;

then squeezed and dried as above, and finally worked for one-half hour in a bath of

Aluminium Acetate 8° Tw.

The material is allowed to steep in this solution 1 hour longer, then wrung and thoroughly dried. The mordant is further fixed by working one-half hour, at a temperature of 115° to 120° F., in a bath containing for every 5 lbs. of material

7½ gallons Water;

1 lb. Whiting;

then rinsed, hydro-extracted, and dried. For the best results this process should be repeated several times.

Rhodamine being of the same character as a basic color may be applied upon a tannin antimony mordant. (See 170.)

**178. Characteristic Properties of the Phthalic Anhydride Colors.** The phthalic anhydride colors are characterized by their *remarkable brilliancy*, and in low percentages they produce the brightest and most delicate of pinks. Their fastness to light is poor and their fastness to washing not much better. Rhodamine is the fastest.

**179. Important Phthalic Anhydride Colors.** The following is a list of the most important phthalic anhydride colors:

The Eosins.

The Rhodamines.

The Erythrosines.

The Phloxines.

The Rose Bengale.

## ACID COLORS.

**180. General Consideration.** The acid colors are so called for two reasons: first, because they are, without exception, acid in character, and second, because they dye wool so readily in an acid bath.

The acid colors are of great importance in wool dyeing, and it may safely be said that seventy-five per cent of all wool dyeing at the present time is accomplished with this class of coloring matters. The acid colors are also of great importance in silk dyeing, but are of practically no importance in cotton dyeing.

Acid dyestuffs may be subdivided into three classes according to their composition.

(1.) Those that are *nitro compounds*, *i.e.*, those containing the nitro group which has the composition ( $-\text{NO}_2$ ) and a valence of one. The nitro compounds are prepared by the action of nitric acid upon certain organic compounds. There are but few members of this class and they all produce yellow to orange colors. *Picric acid* and *naphthol yellow* are the best examples.

(2.) The *sulphonated basic colors*, *i.e.*, those which are prepared by the action of sulphuric acid upon various basic colors. During this action the characteristic properties of the basic dyestuffs are lost, but they are at the same time converted into acid dyestuffs producing similar colors, and although their coloring power is reduced, their fastness is usually correspondingly increased.

(3.) Those that are *azo compounds*, *i.e.*, those containing one or more azo groups, which have the following chemical structure ( $-\text{N}=\text{N}-$ ). The dyestuffs of this class are by far the most numerous and valuable of the acid colors.

**181. Application of Acid Colors to Wool.** The acid dyestuffs, almost without exception, go on wool readily in an acid bath and the dyeing process is comparatively simple.

The dye bath is usually prepared as follows:

Necessary amount of Dyestuff (usually 1 to 5 per cent);  
10 to 15 per cent of Sodium Bisulphate;  
or  
10 to 15 per cent of Sodium Sulphate (Glauber's Salt);  
3 to 5 per cent of Sulphuric Acid.

The material is entered into the dye bath at a temperature of  $140^{\circ}$  to  $180^{\circ}$  F., brought to a boil and dyed at a boil for forty-five minutes

to one hour, at the end of which time the dyestuff is, as a rule, entirely taken up by the wool; or, to use the common expression of the dyer, "*The dye bath is completely exhausted of color.*"

Most of the acid dyestuffs go on the fiber evenly, or dye level, when applied by the above method, but with such colors as do not readily dye level, it is advisable to commence the dyeing with 2 to 5 per cent acetic acid, instead of sulphuric acid, and add 2 to 3 per cent sulphuric acid towards the end of the dyeing to complete the exhaustion of the color from the dye bath.

**182. Application of Acid Colors to Silk.** In the application of acid dyestuffs to silk it is customary to use a bath of "boiled-off liquor" to which sulphuric acid has been added.

The dye-bath for 10 lbs. of silk is prepared as follows:

2 to 4 gallons of "Boiled-off Liquor".  
10 to 12 " " Water.

Necessary amount of Dyestuff.

Sufficient sulphuric acid to render the dye bath decidedly acid.

Begin the dyeing at 100° to 125° F. and eventually raise the temperature to 200° F., but no higher.

The acid dyestuffs may also be applied to silk without the use of boiled-off liquor. In this case the dye bath is made acid with acetic acid, and the sulphuric acid is not added until the temperature has been raised to 200° F.

**183. Application of Acid Colors to Cotton.** The acid dyestuffs are seldom used for cotton dyeing, as there is no direct affinity between cotton and the colors of this class, and furthermore no satisfactory process has ever been devised for applying them to cotton. A few of the acid scarlets are occasionally used for the coloring of cotton material where good fastness to light is desirable, but where the material will never be subjected to washing, as for instance with cloth that is to be used for book covers and for decorative purposes.

The dyeing process is carried on in a very concentrated or "*short*" bath containing:

Necessary amount of Dyestuff (usually 5 to 10 per cent).  
5 to 10 per cent of Alum.  
25 to 50 per cent Common Salt or Glauber's Salt.

The temperature of the dye bath is raised to 120° F., the material entered and worked ten to fifteen minutes at this temperature, and then



from one-half to three-quarters of an hour longer in the gradually cooling bath. It is then wrung evenly, and dried without washing.

The acid dyestuffs are often used in the coloring of paper (vegetable fiber).

**184. Dyeing of Woolen and Worsted Cloth Containing Cotton, with Acid Colors.** Many two-color effects may be pro-

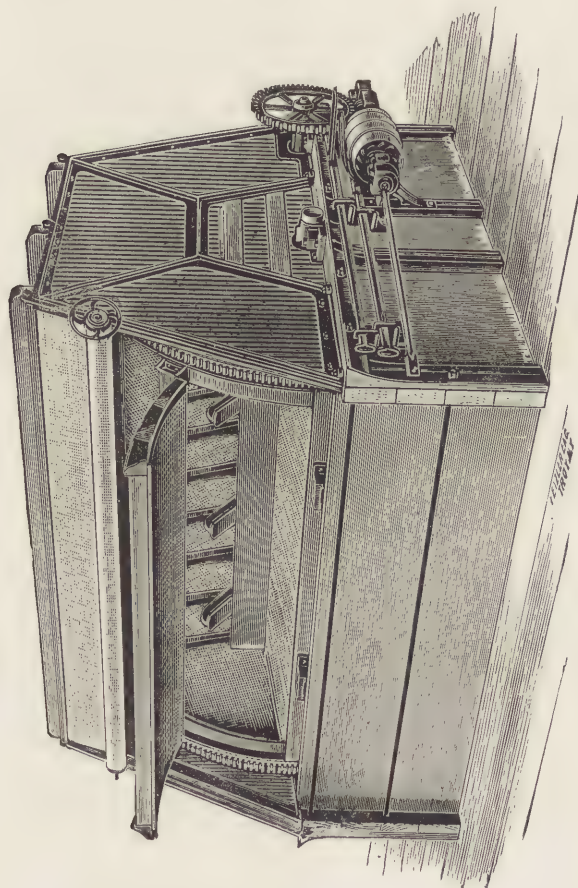


Fig. 60. Klaunder-Weldon Dyeing Machine for Loose Stock.

duced upon woolen or worsted cloth containing cotton by the proper application of acid dyestuffs. Thus, if worsted cloth containing a white cotton thread is dyed with certain acid blacks, the cotton thread will not even be stained, whereas the wool will be dyed black. By working this same dyed cloth in a dye bath con-



taining a direct cotton pink or red, the white cotton thread would be dyed pink or red, whereas the black would not be materially affected. Two-color effects, known as *shot effects* are thus produced, and the process is sometimes known as *cross dyeing*.

**185. General Properties of the Acid Colors.** The number of acid dyestuffs is so great and their properties so varied, that it is difficult to assign definite properties that will apply to all.

They are readily taken up by wool and silk in an acid bath, but for cotton and linen they have no affinity. Jute apparently has some direct affinity for certain acid dyestuffs.

Most of the acid colors are easily soluble in water, and dye the fiber evenly, and the dyestuff is as a rule entirely extracted or exhausted from the dye bath.

The acid colors include some very fast, and, at the same time, some very fugitive colors. Between these limits they include colors of all degrees of fastness.

#### 186. List of Some of the Important Acid Colors:

REDS.	Milling Orange.	Victoria Violet.
Acid Eosine.	Orange I, II, III, etc.	Wool Violet.
Acid Magenta.	BLUES.	YELLOWS.
Anthracine Red.	Alizarine Blue S. A. P.	Acid Yellow.
Azo Bordeaux.	The Alkali Blues.	Alkali Yellow.
Azo Cardinal.	The Nicholson Blues.	Chrysoine.
Azo Carmine.	Azo Acid Blue.	Curcumeine.
Azo Cocchine.	Basle Blue.	Fast Yellow.
Azo Cochineal.	Bavarian Blue.	Indian Yellow.
Azo Fuchsine.	Coomassie Navy Blue.	Metanil Yellow.
Azo Eosine.	Fast Navy Blue.	Milling Yellow.
Bordeaux B.	Fast Wool Blue.	Naphthol Yellow
Brilliant Bordeaux.	Milling Blue.	New Yellow.
Brilliant Croceine.	Naphthalene Blue.	Picric Acid.
Brilliant Cochineal.	New Victoria Blue.	Tartrazine.
Brilliant Ponceau.	Patent Blue.	Tropaeoline.
The Chromotropes.	Pure Blue.	Uranine.
The Cloth Reds.	Silk Blue.	GREENS.
The Fast Reds.	Soluble Blue.	Acid Green.
Palatine Red.	Water Blue.	Alkali Green.
The Ponceaus.	Wool Blue.	Fast Green.
Scarlets G. R. and S.	VIOLETS.	Guinea Green.
Sorbine Red.	Acid Violet.	Milling Green.
Wool Scarlet.	Alkali Violet.	Naphthalene Green.
ORANGE.	Azo Acid Violet.	Neptune Green.
Aniline Orange.	Formyl Violet.	New Acid Green.
Aurantia.	Guinea Violet.	Patent Green.
Crocein Orange.	Lanacyl Violet.	Wool Green.

## DIRECT COTTON COLORS.

**187. General Consideration.** Great difficulty was at first experienced in the production of dyestuffs that would color cotton directly. The *basic*, *acid*, and *phthalic anhydride* colors all dyed wool and silk directly, but they had little if any direct affinity for

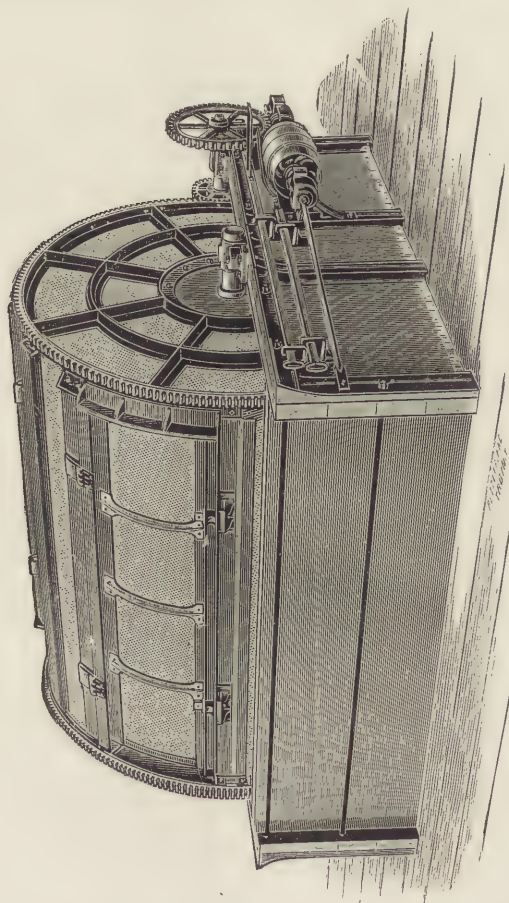
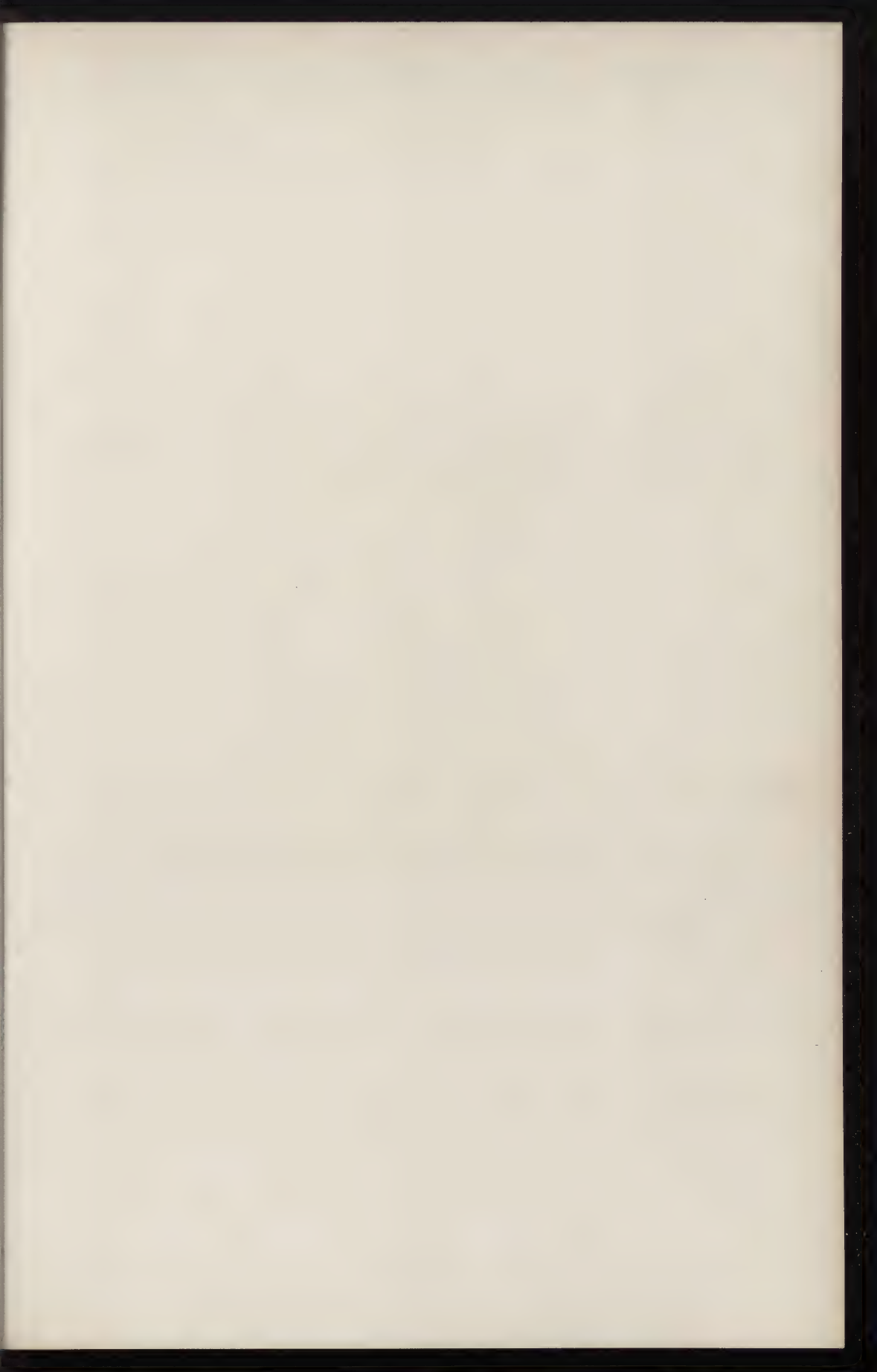
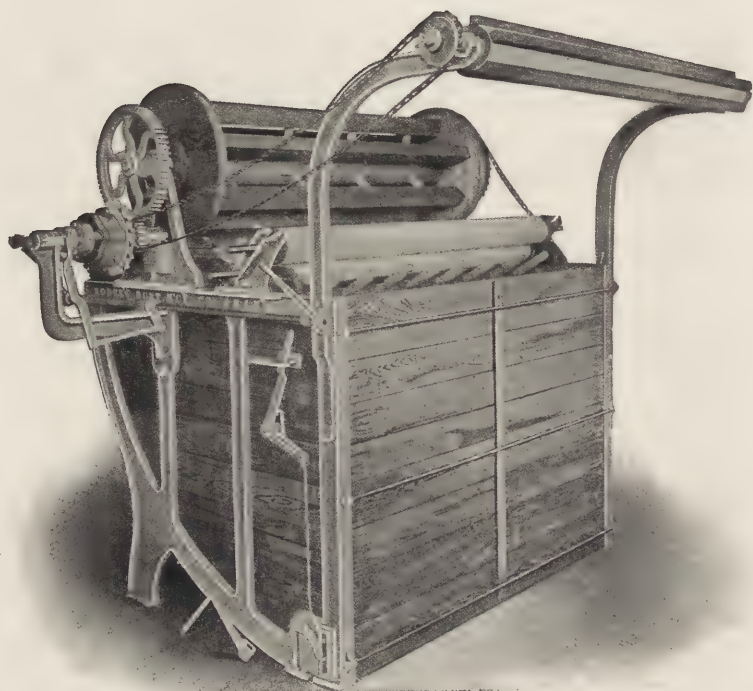


Fig. 61. Klander-Weldon Dyeing Machine. Top Removed to Show Cylinder.

cotton, and even when mordants were used the acid colors could not be satisfactorily applied to that fiber. The production of a group of dyestuffs that would color cotton as easily as the acid colors dye wool, was therefore, the goal towards which color chemists were striving, and in 1884, Böttiger, a German chemist, discovered *Congo Red*, the first of the so-called *Direct Cotton*





IMPROVED DYEING MACHINE FOR CLOTH AND KNIT GOODS IN THE PIECE

Rodney Hunt Machine Co.



*Colors.* The discovery of many others soon followed, and at the present time the direct cotton colors are more numerous than any other class, and are capable of producing nearly every color; although up to the present time no direct cotton blues or greens have been discovered, that are as brilliant as the basic blues and greens.

**188. Application to Cotton.** Cotton material may be readily dyed in a water solution of any direct cotton color, without any further addition to the dye bath. This method, however, is seldom if ever used practically, for it has been found that the addition of certain assisting substances such as sodium chloride (common salt), sodium sulphate (Glauber's salt), and sodium carbonate, brings about a far better extraction of the coloring matter from the dye bath, and more even dyeings.

The four dyeing methods which follow are most frequently used for cotton dyeing, but these are sometimes modified to suit special conditions.

#### FIRST METHOD.

This method may be considered the one of widest application and may be used with the majority of cotton colors and for nearly all shades. It consists in dyeing with soda ash and Glauber's salt, or soda ash and common salt.

Prepare the dye bath with:

	DARK SHADES.	MEDIUM SHADES.	LIGHT SHADES.
Direct Cotton Color.	3 % or more.	1 to 3 %.	1 % or less.
Glauber's Salt (Crystals).	20 to 30 %.	10 to 20 %.	5 to 10 %.
Soda Ash.	5 %.	2 %.	1 %.

For dark shades enter the material into the dye bath at a temperature of from 120° to 170° F, and for light shades from 100° to 120° F. Bring the dye bath to a boil, and continue the dyeing at a boiling temperature for one hour. The material is then taken from the dye bath, rinsed once or twice in cold water to remove excess of salt, and then dried.

#### SECOND METHOD.

Dyeing with Glauber's salt or common salt, with no other addition.

Prepare the dye bath with:

	DARK SHADES.	LIGHT SHADES.
Direct Cotton Color.	3 % or more.	Less than 3 %.
Glauber's Salt (Crystals) or Common Salt.	20 to 30 %.	10 to 15 %.

This method is used principally for dyestuffs which are extracted from the dye bath slowly, and for the production of deep shades. If the water used is calcareous a little soda ash ( $\frac{1}{2}$  % of weight of goods usually enough) should be added. Dyeing directions are the same as for the first method.

### THIRD METHOD.

This method should be used where slow dyeing is necessary, with goods that do not penetrate easily, and in the dyeing of delicate tints and compound shades, that are not easily matched.

Prepare the dye bath as follows:

	LIGHT SHADES AND TINTS.	MEDIUM.	DARK.
Direct Cotton Color	1 % or less	1 to 3 %	3 % or more
Common Salt	2 %	5 %	15 %
Soap	2 %	3 %	5 %

Enter the material at a temperature of 100° F or lower, into the dye bath containing the dyestuff and soap, and after working  $\frac{1}{4}$ -hour, add the proper quantity of common salt. Bring dye bath to a boil, and dye at a boil for one hour. Calcareous water should be corrected as in the second method before adding the soap.

### FOURTH METHOD.

This method is the same as the third, except that sodium phosphate is used instead of common salt.

**General Notes.** When especially deep shades are desired it often is advisable to boil for  $\frac{1}{2}$ -hour and then work in the gradually cooling bath for  $\frac{1}{2}$  to 1 hour, for by doing this the dyestuff is utilized to its fullest extent.

Some dyestuffs have been found to dye as well or better when entered into the boiling dye bath instead of at a lower temperature.

In some cases where a boiling dye bath is not desirable, the dyeing may be done at a lower temperature (160° to 180° F.), but this as a rule is not economical as regards the quantity of dyestuff used.

With colors that are very fugitive to washing, the rinsing after dyeing is sometimes dispensed with, but dyeings finished in this way will not stand even the mildest washing without running.

**Notes on Dissolving Dyestuffs.** It is far more convenient as well as safer to keep dyestuffs that are constantly used, in solu-

tion rather than in the dry powder state. In many works it is customary to keep large stock solutions on hand, generally so much color to the gallon, but for laboratory work the metric system is used, and a certain number of grams dissolved per litre. By using a certain volume of these solutions an exact weight of dyestuff may be had without the necessity of making a weighing before each dyeing.

It is essential that all the dyestuff be *completely dissolved* before its addition to the dye bath, for solid particles of the undissolved dyestuffs coming in contact with the goods, form spots which are removable with great difficulty, and sometimes not at all. For this reason it is well to strain the dyestuff solution through fine cotton cloth or flannel before adding it to the dye bath.

In the best regulated dye-houses no dyestuffs in the dry or powdered form are allowed in the dye-house proper, but are dissolved in a separate room. Much weighing is thus obviated, and the specks and unevenness upon the dyed goods, due either to the addition of the dry powder to the dye bath, or from small particles of the same settling from the air upon damp goods, is prevented.

**Proportion of Water Used in Dye Stuffs.** The degree of concentration of the dye bath is an important factor in the dyeing of cotton with the direct cotton colors, for the more concentrated the dye bath the more easily the coloring matter is absorbed by the material, and the more thoroughly extracted from the dye bath. The only advantage of using a dilute bath is in the production of light shades and tints. In general, the quantity of water added to the dye bath should be from 15 to 25 times the weight of material being dyed.

**After Treatment with Metallic Salts.** Cotton material dyed with certain of the direct cotton colors is rendered much faster to light and in many cases somewhat faster to washing by an after treatment with some metallic salt.

The after treating agent most frequently used is *copper sulphate* (*blue vitriol*), either alone or with *potassium bichromate*. The combination of the two seems to be most likely to increase the fastness to washing.

This after treatment has the disadvantage of dulling the original shade, but with some experience the dyer can usually satisfactorily allow for this change.



When copper sulphate and potassium bichromate are used the quantities are as follows for 100 lbs. of dye material, depending upon the depth of the shade.

1 to 2 lbs. Bichromate of Potash.

1 to 2 lbs. Copper Sulphate.

1 to 2 lbs. Acetic Acid.

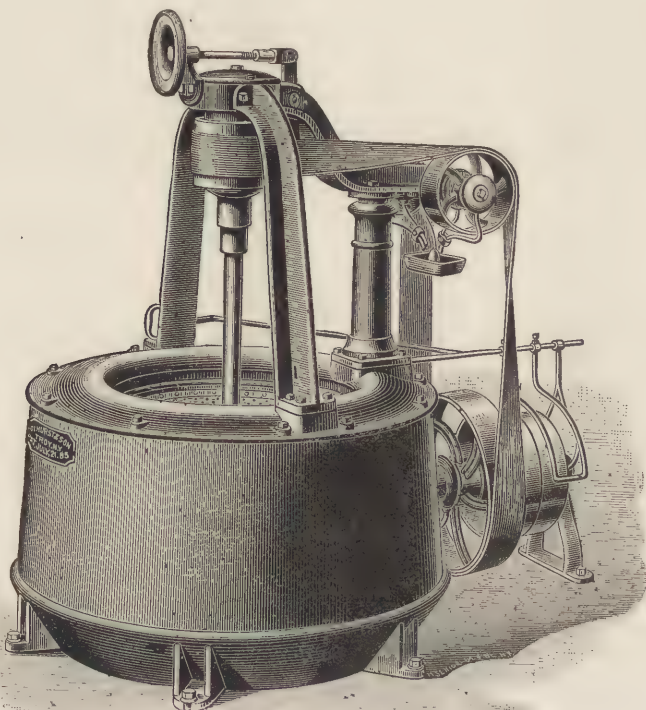


Fig. 62. Tolhurst's Hydro-Extractor.

The after treatment is carried on in a boiling bath for about  $\frac{1}{2}$ -hour.

The bichromate of potash is often omitted when fastness to washing is of less importance than fastness of light.

Other copper and chromium salts, and salts of iron, aluminium, and nickel, are occasionally used.

**Coupling or Diazotising and Developing.** Cotton material dyed with direct cotton colors, particularly blacks, blues, and browns, may sometimes (depending upon their composition) be rendered



much faster to washing and greatly increased in intensity by the process known as *coupling or diazotising and developing*.

The process is as follows:

The material which has already been dyed by one of the regular methods (already described), is rinsed in cold water and *diazotized* by working fifteen to twenty minutes in a cold bath made up as follows for 100 lbs., dyed material:

	DARK SHADES.	MEDIUM OR LIGHT SHADES.
Sodium Nitrite,	2½ lbs.	1½ lbs.
Hydrochloric Acid (32° Tw.)	7½ lbs.	5 lbs.

Then rinse in cold water containing a little hydrochloric acid and then *develop* or *couple* by working for ten to fifteen minutes in a cold bath containing the developer (usually ½ to 2 lbs.) dissolved in caustic soda solution. The material is then washed and dried.

NOTE—The developers most frequently used for this purpose are beta naphthol, alpha naphthol and phenylene diamine.

**189. Application of Direct Cotton Colors to Wool.** Wool may be dyed with nearly all the direct cotton colors in a neutral or weak soap bath, with or without the addition of Glauber's salt or common salt. In many cases the dye bath seems to work the best when slightly acidified with *acetic acid*. If the bath is made too strongly acid the wool absorbs the dyestuff too rapidly and uneven dyeing is likely to result, which unfortunately can not be improved by continued boiling, as is the case with the cotton material.

With material likely to dye unevenly it is best to start with a neutral bath, or with the addition of as little acid as possible, and when the color has been nearly all extracted add a little acid to assist in exhausting the color more completely.

The following is a general method for dyeing wool with direct cotton colors:

For light shades dye with the addition of 10 per cent Glauber's salt, or in case the material has a tendency to dye unevenly add 10 per cent Glauber's salt and 5 per cent ammonium acetate. Enter material at 180° F and dye at a boil for one hour. If the bath does not exhaust sufficiently add 1 to 2 per cent of acetic acid toward the end of the dyeing.

For dark shades, begin the dyeing with the addition of 10 to 20 per cent of Glauber's salt and 1 to 2 per cent of acetic acid. Enter at 180° F. and dye at a boil for one hour. If the dye bath does not exhaust sufficiently add 2 to 3 per cent of acetic acid toward the end of the dyeing.

NOTE—The ammonium acetate may be made by neutralizing ammonia with acetic acid.

**After Treatment.** In many cases an after treatment of the dyed material with certain metallic salts increases its fastness both to milling, washing, and light. In many cases this after treatment is of great importance.

The after treatment usually consists in adding to the dye bath at the end of the dyeing operation, one of the following:

- 1 to 4 per cent of Potassium Bichromate.
- 1 to 3 per cent of Chromium Fluoride.
- 1 to 5 per cent of Copper Sulphate.

and then continuing the boiling for  $\frac{1}{2}$  to 1 hour longer.

This after treatment is sometimes carried out in a separate bath.

**190. Application of Direct Cotton Colors to Silk.** The direct cotton colors are applied to silk in much the same manner as to wool. If boiled off liquor can be obtained, its use is advantageous.

The dye bath is best made up with

Dyestuff, necessary amount	(1 to 5 per cent).
Boiled-off Liquor	$\frac{1}{2}$ dye bath.
Glauber's salt	5 to 10 per cent.
Acetic Acid	1 to 3 per cent.

Enter at 140° F., raise very slowly to a boil, and dye at a boiling temperature.

Care must be taken not to make the bath too acid nor to commence the dyeing at too high a temperature, as these conditions cause too rapid absorption of the dyestuff, and consequently the production of uneven dyeings.

**191. Application of Direct Cotton Colors to Cotton and Wool (Union Material.)** The direct cotton colors having a direct affinity for both cotton and wool are extensively used in dyeing material composed of these fibres and commonly known as *union goods*.

By proper choice of dyestuffs, and regulation of the process such material may be dyed evenly, and almost any color, in one bath.

**192. Properties of the Direct Cotton Colors.** The direct cotton colors vary greatly in fastness. In general they are not extremely fast to light or washing, and some, particularly the reds, are very sensitive to acids. A few, however, possess very good fastness, which is often increased by an after treatment with metallic salts, or by the diazotising and developing process.

The property known as "*bleeding*" is one of the valuable, as well as one of the detrimental characteristics of the direct cotton colors.

This property is well illustrated by the following experiment: Take a beaker of water and introduce into it a skein of yarn dyed with a direct cotton color and a skein of un-dyed yarn. Boil the two for a hour, when it will be found, in many cases, difficult to distinguish one skein from the other. The color has run or "*bled*" from the dyed skein and been taken up by the un-dyed.

This property is valuable since it tends to produce very level dyeings, and also to correct unevenness. On the other hand it is detrimental as it prevents the use of the direct cotton colors for coloring of ginghams and in calico printing.

The direct cotton colors are much faster to washing when dyed upon wool than when on cotton.

The direct cotton colors are, as a rule, readily soluble in water.

**193. List of Important Direct Cotton Colors.** Under this head it will be unnecessary to give a list of the several hundred direct cotton colors, for the method adopted in naming them is more or less uniform.

The Casella Color Company, who are among the leaders in the manufacture of this class of colors, designate them as *Diamine* Colors, e.g., *diamine red*, *blue*, *green*, etc.

The Farbenfabriken Co. designate them as *benzo* and *chloramine* colors.

The Meister, Lucius, and Brüning Co. (H. A. Metz) designate them as the *dianil* colors.

The Badische Aniline and Soda Fabrik (Kuttruff and Pickhardt) designate them as *pyramine* and *oxamine* colors.

The Berlin Aniline Works designate them as *Congo*, *Columbia*, and *Chicago* colors.

American Dyewood Co., as *Tetrazo* colors.

Levenstein and Co. (Thos. Leyland and Co.) as *Dianol* colors.

The terms direct and cotton, as direct blue, direct green, cotton blue, etc., are very extensively used.

## THE SULPHUR OR SULPHIDE COLORS.

**194. General Consideration.** It was discovered as early as 1873, that by fusing sodium sulphide with sawdust, and extracting the fused mass with water, a dark brown coloring matter could be obtained which dyed cotton directly a brownish color. Further experimenting along this line led to the manufacture of a marketable coloring matter designated as *Cachou de Laval*, which was the first of the so-called *Sulphur Colors*.

**Cachou de Laval** was extensively used for many years after its discovery, for it could be applied to cotton easily, and the brown-

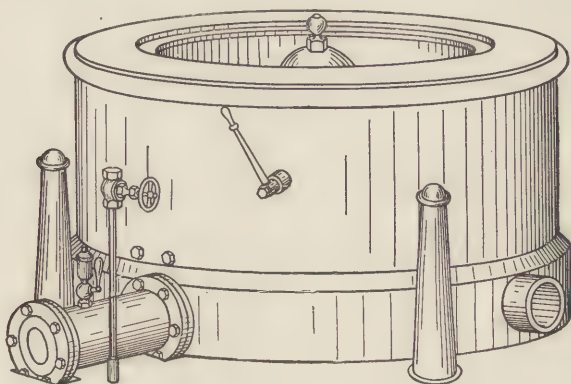


Fig. 63. Hydro-Extractor Underneath Driven.

ish shades which it produced possessed excellent fastness to light and washing. The process by which it is applied is somewhat different from that used for the more recent sulphur colors. It is as follows :

The coloring matter is dissolved in boiling water, and when solution is complete, sodium chloride, sulphate or bisulphate is added to the dye bath. The dyeing, which is done at just below a boiling temperature for from one-half to one hour, is followed by an after treatment at 180° F., in a bath containing one of the following reagents:

Sulphuric Acid, 2 to 3 ounces per gallon.

Hydrochloric Acid, 5 to 7 ounces per gallon.

Potassium Bichromate,  $\frac{1}{4}$  ounce per gallon.

Copper Sulphate,  $\frac{1}{2}$  to  $\frac{3}{4}$  ounces per gallon.

The shades produced vary somewhat with the after-treating agent used, mineral acids giving the yellowish shades.



Strange to say, twenty years elapsed before the second sulphur color made its appearance; for it was not until 1893 that Vidal produced the color which has since borne his name (Vidal Black). The success of this color caused color chemists and manufacturers to turn their attention to the study of possibilities along this line, and their labors have been rewarded, for we now have sulphur dyestuffs of almost every color except red; no sulphur red having yet been prepared.

The *sulphur* or *sulphide colors*, as they are often called, are in many respects similar to the direct cotton colors; but they differ so entirely in certain other respects that we place them in a group by themselves. In recent years they have become an important factor in cotton dyeing, on account of the fastness of the dyeings they produce, and they are now extensively used for the production of fast blacks, blues, browns, and compound shades upon cotton.

They are called sulphur colors for three reasons: In the first place, sulphur is a constituent of all of the dyestuffs of this class; sulphur and sodium sulphide are largely used in their manufacture; and finally, sodium sulphide is almost without exception a necessary constituent of the dye bath during their application.

**195. Application of the Sulphur Colors.** The sulphur colors are used only for the dyeing of vegetable fibers. The chief reason for this being the fact that they must be applied in an alkaline bath; a condition unfavorable to the dyeing of animal fibers. The application of the sulphur colors may be best discussed under the following heads:

Preparation of Dye Bath.

Dyeing Process.

After Treatment.

Machinery Used.

**Preparation of Dye Bath.** In general, the sulphur colors are applied in a dye bath made up as follows:

Dyestuff, 1 to 20 per cent, depending upon shade and character of dyestuff used.

Sodium Sulphide, 1 to 4 times the weight of dyestuff used.

Soda Ash, 5 to 10 per cent.

Caustic Soda (when necessary),  $\frac{1}{10}$  weight of dyestuff.

Common Salt or Glauber's Salt, 20 to 50 per cent.

Most of the sulphur colors are either insoluble or only slightly soluble in water, but dissolve readily in a solution of *sodium sulphide*. It is, therefore, necessary to dissolve the dyestuff thoroughly in a solution of sodium sulphide before adding it to the dye bath. With some of the sulphur colors it is only necessary to use double their weight of sodium sulphide or even less; but as a rule, three times their weight is better. Where there is a constant agitation of the dye liquor in the presence of air, as is the case in jig dyeing, and many other forms of dyeing machinery, four times their weight is advisable.

The *soda ash* serves to keep the dye bath alkaline, which condition is necessary in order to prevent the decomposition of the sulphur compounds present. Decomposition, with the evolution of large quantities of hydrogen sulphide, readily takes place if the dye bath is in the least degree acid.

*Caustic soda* is sometimes used with dyestuffs which decompose readily, and this serves to react with the escaping hydrogen sulphide, thus forming sodium sulphide, which remains in the dye bath.

The soda ash is commonly dissolved first of all in the dye bath at a boil, and the previously dissolved dyestuff then added.

The *salt* used, whether *common salt* or *Glauber's salt*, is added next, and the bath boiled for a few minutes and any scum removed. These salts act as *leveling agents*, and facilitate the exhaustion of the dye bath. As a rule the darker the shade desired, the greater the quantity used.

In special cases, other additions are sometimes made to the dye bath, such as dextrine, glucose, molasses, Turkey-red oil and petroleum.

The *quantity of dye liquor* and its *concentration* depends upon the depth of shade desired and form of apparatus used. In general the proportion may be given as follows:

For raw stock and yarn dyeing in any form of open kettle, twenty to twenty-five parts of liquor to one of material dyed.

For jig dyeing, five parts of liquor to one of material.

With various form of closed apparatus, the amounts vary between these limits.

**Process.** The material to be dyed is entered at, or just below,

the boil. While a few sulphur colors may be dyed to advantage at a boil, it is customary to turn off the steam just after the dyeing commences, and occasionally turn it on during the dyeing in order to prevent the temperature from falling below 195° F. In most cases a continuous boiling is not recommended. With some dyes (Immedial sky blue, for instance) a lower temperature is desirable. The dyeing is usually continued for one hour, but this time may be reduced for light shades.

Although not absolutely necessary, with the majority of the sulphur colors, it is advisable to keep the material below the surface of the dye liquor as much as possible. A continued contact with the air causes a precipitation of the free coloring matter which may result in unevenness and bronzy dyeings.

Immediate wringing and rinsing is essential in most cases for the attainment of the best results, and in general the more thor-

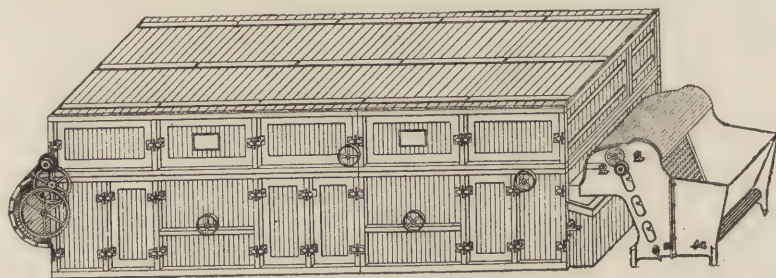


Fig. 64. Kitson Dryer.

oughly and evenly the material is wrung and rinsed after dyeing, the greater will be the fastness to rubbing, and the less the liability of unevenness. It is economical to return the first rinse water, which contains a relatively large amount of dyestuff, to the dye bath or to use it in dissolving the next lot of dyestuff. Should the shade produced be too deep, it may be partially stripped by working for a few minutes in a hot bath of sodium sulphide.

As with the direct cotton colors, the dye bath does not become exhausted, and a standing bath is used whenever possible. As a rule, the proportion of ingredients may be reduced as follows:

	FIRST BATH.	SECOND BATH.	THIRD AND FOLLOWING.
Dyestuff.....	10%	7½%	5 to 6%
Sodium Sulphide....	30%	15%	10 to 12%
Sodium Carbonate..	10%	4 to 5%	2 to 3%
Salt.....	50%	10 to 15%	3 to 5%



In general, the specific gravity of the standing bath should be kept above 10° Tw. for black and very heavy shades.

**After Treatment.** With many of the sulphur colors, no after treatment is necessary, but with others, an after treatment is beneficial, and in some cases it is necessary. The after treatment consists of one of the following:

- (1) A treatment with some Metallic Salt. (Usually of chromium, copper or zinc.)
- (2) A treatment with Acetate of Soda, or some Alkali.
- (3) Oxidation or Ageing, by exposure to steam and air, or with Sodium Peroxide.

(1) **METALLIC SALTS.** A number of sulphur blacks and browns are rendered faster or the shade favorably modified by an after treatment with potassium bichromate copper sulphate or zinc sulphate. This after treatment follows the squeezing and washing of the dyed material and usually consists in treating for one half hour in a fresh bath at 160° F., which contains one of the following combinations:

- (a) 1 to 3% potassium bichromate,  
2 to 3% acetic acid.
- (b) 1 to 3% copper sulphate,  
2 to 3% acetic acid.
- (c) 1 to 2% potassium bichromate,  
1 to 2% copper sulphate,  
2 to 3% acetic acid.
- (d) 3% potassium bichromate,  
5% caustic soda, solution 40° Beaumé.
- (e) 2% chromium flouride,  
2% acetic acid.
- (f) 3 to 5% zinc sulphate,  
3 to 5% sodium acetate.

(2) **ACETATE OF SODA AND OTHER ALKALINE REAGENTS.** An after treatment with sodium acetate,\* or some alkaline reagent such as borax, ammonia, or soda, is advisable, particularly with sulphur blacks, and for union goods containing cotton warps dyed with sulphur colors which have been cross dyed with acid colors. Such treatment prevents, during storage, the deteriorating action of any acid that may remain upon the cotton.

\*NOTE.—The application of acetate of soda for union material dyed with sulphur colors is patented by the Cassella Color Co., but may be used without restriction with their immiedial colors.



(3) OXIDATION OR AGEING. A number of the sulphur blues require an after oxidation to fully develop their color. This is particularly true of such colors as *Immedial blue C* and *C R*, *Thiogene blue B*, which come from the dye bath a bluish gray color, but which develop into a dark blue when heated for an hour in a mixture of steam and air at a temperature of 180 to 200° F.

The apparatus used for this ageing should be so constructed that the air and steam will be well mixed as they enter, and will then thoroughly penetrate the dyed material. The steam should be admitted at the bottom so that the condensed water may easily run off, for if it comes in contact with the dyed material, spots will result. The hotter and drier the steam, the brighter and the more rapid the development of the color.

These blues may also be developed by the process called smothering, which consists in allowing the dyed material to lie in a pile several hours, or over night during which period the oxygen of the air should bring about the required oxidation. This should be done in a room at a temperature of 140 to 160° F.

When developed by either of the above oxidation processes, the dyed material should not be rinsed, but should be freed from dye liquor by hydro-extracting or squeezing.

This oxidation may also be brought about by the use of *sodium peroxide*, but this method is seldom used, as the steaming and smothering processes are so much cheaper.

**Apparatus.** The most essential requirement of apparatus used for dyeing sulphur colors is that it must have *no copper* or *brass* parts, as these are rapidly and seriously attacked by the sulphur compounds present in the dye bath, and the copper becomes converted into the black copper sulphide. For this reason the apparatus for dissolving the dyestuff as well as for the dyeing must be constructed of wood, iron or nickel. Lead-lined iron vessels have been found to be very durable.

Various forms of machines are largely used for the dyeing of *loose cotton* or *raw stock* as it is called, both with direct cotton colors and sulphur colors. Of these, the Klauder-Weldon, made by the Klauder-Weldon Co., at Amsterdam, N. Y.; the Delahunty; one made by the Vacuum Dyeing Machine Co., Chattanooga,

Tenn.; and the Cohnen Dyeing Machine, A. Klipstein & Co., American Agents, are all worthy of mention.

The Klauder-Weldon Apparatus (Figs. 60 and 61) consists of a perforated drum, containing several compartments (made of iron for sulphur colors) which revolves in the dye bath. This machine is extensively used for all forms of loose cotton dyeing.

The Delahunty is similar in principle to the Klauder-Weldon, the chief difference being in the compartmental structure of the drum.

With the raw stock machines already described the washing of the material may be accomplished within the machine before its removal. After washing it is passed through a hydro-extractor, and then through some form of dryer.

A *hydro extractor* is a machine used for rapidly removing the excess of liquor from textile material. It consists of a cylindrical metal container with a perforated outer surface which revolves rapidly within an outer shell. As the container or *basket* revolves, any excess of water held by the material within is violently thrown through the perforations by centrifugal force. Hydro-extractors are of two general types, the overhead driven, illustrated in Fig. 62, and the underneath driven, in Fig. 63.

*Dryer.* When large quantities of raw stock are dyed, the drying is usually accomplished in some form of a mechanical dryer. The Kitson Dryer,

Fig. 64, made by the Kitson Machine Co., Lowell, and the Hurricane Dryer, Fig. 65, made by the Philadelphia Textile

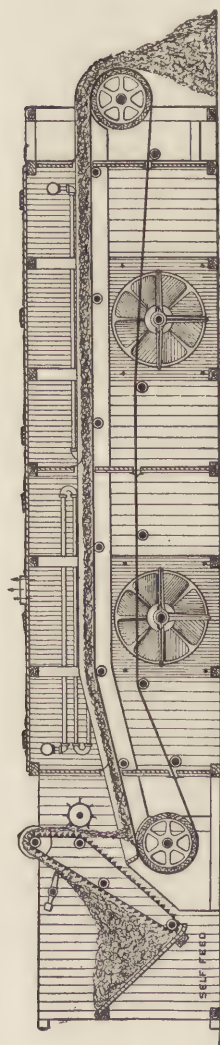


Fig. 65. Sectional Elevation of the Hurricane Dryer.

Machinery Co. of Philadelphia, are good examples. They consist of a long continuous apron which carries the damp stock between coils of steam pipes. The whole apparatus is covered with a wooden structure which is well ventilated with fans.

The Vacuum Dyeing Machine (Fig. 66) consists of a circular iron tub T, with a loose perforated bottom upon which the cotton is packed. A perforated top is then placed upon the cotton, and the heavy cover C securely bolted on to the tub T. When in operation, the dye liquor is forced into the tub beneath the perforated

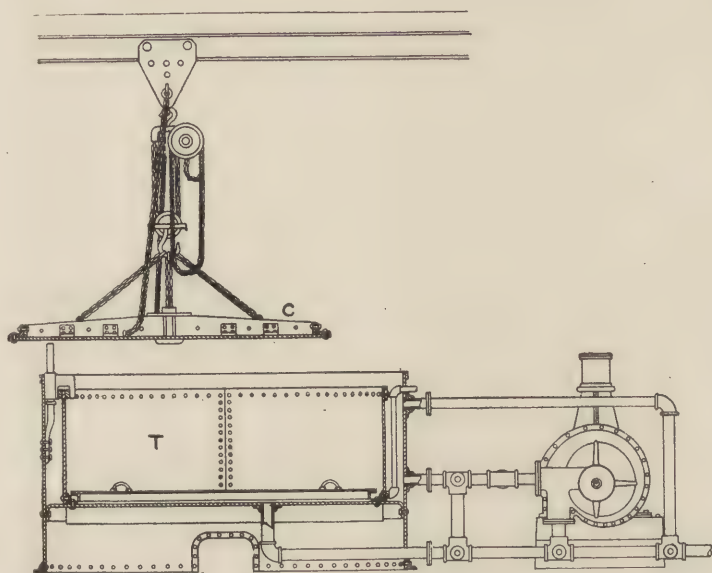


Fig. 66. Vacuum Dyeing Machine.

bottom, from whence it passes up through the cotton and finally returns to the pump through a pipe which leads from the top. In this way a positive circulation of the dye liquor is kept up as long as necessary. When the dyeing is completed the whole batch of compressed cotton (resembling in shape an enormous cheese) can be removed at one time by an overhead hoist. This apparatus gives very even dyeings, and reduces the cost of labor and dyestuff to a minimum.

The Cohnen Centrifugal Dyeing Machine (Fig. 67) is so constructed that the material can be boiled, dyed, washed and hydro-



extracted without being removed from the machine. It consists of an upright drum, made up of separate compartments, into which the material is packed under pressure. These compartments all communicate with each other, and the liquor is forced into one, which we will call the first, and passes from the last compartment back to the pump. It is suitable for every kind of fiber that permits of being packed and pressed in boxes.

Inside the plain, unperforated centrifugal drum shown in Fig 68 is an inner chamber *a* into which the dye liquor is forced

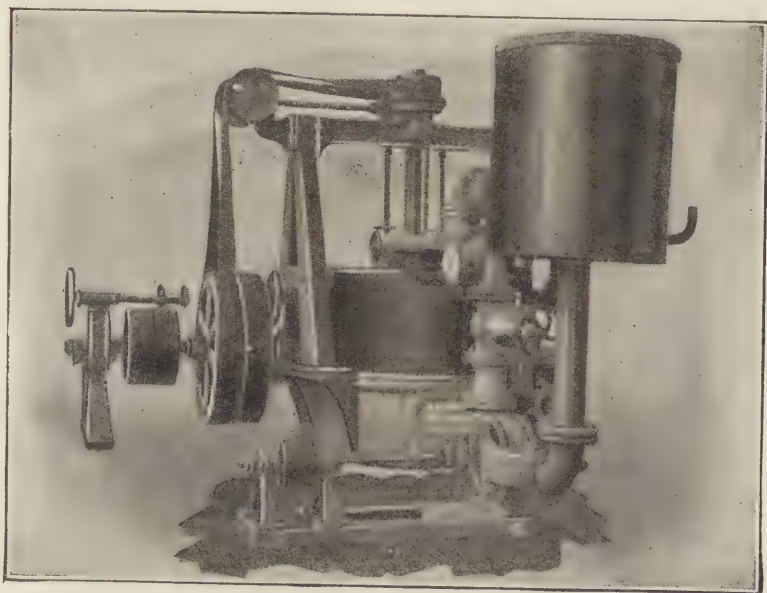


Fig. 67. Cohnen Centrifugal Dyeing Machine.

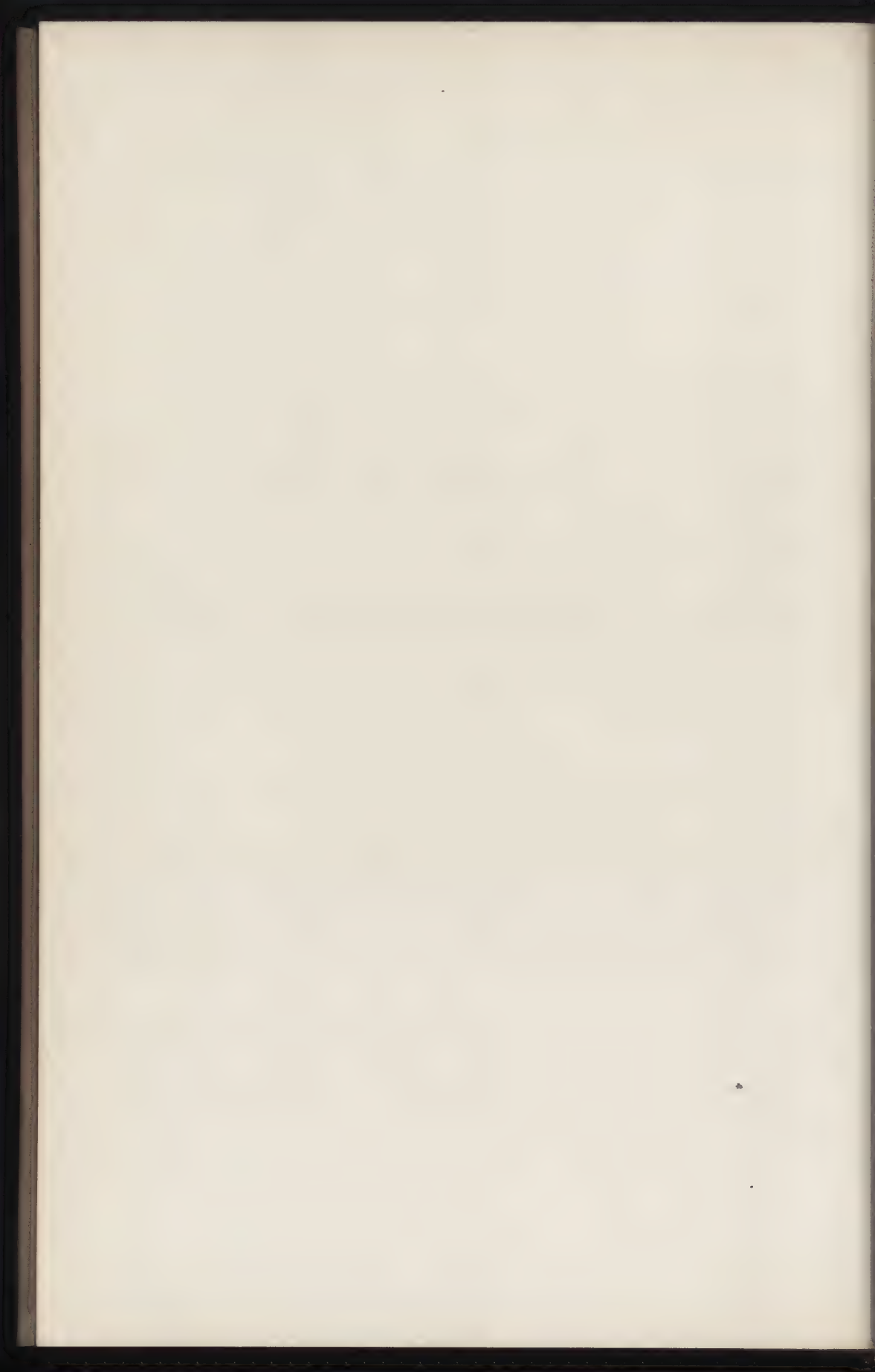
by means of a centrifugal pump *b* through either the pipe *d* or *g*. This inner chamber is in direct communication with a set of partially perforated boxes *c* into which the material to be dyed is packed. After the liquid has entered by the pipe *d*, it passes from the inner chamber *a* into the boxes, saturates the material, flows into and fills the collecting chamber *f*, then leaves the machine by the pipe *g*, returning thence to the pump to circulate again in the manner described. The conduit pipes *d* and *g* are so constructed that they can be easily disconnected from the drum, in which case





SULPHUR BLACK HOSIERY DYEING MACHINE

Klander-Weldon Dyeing Machine Co.



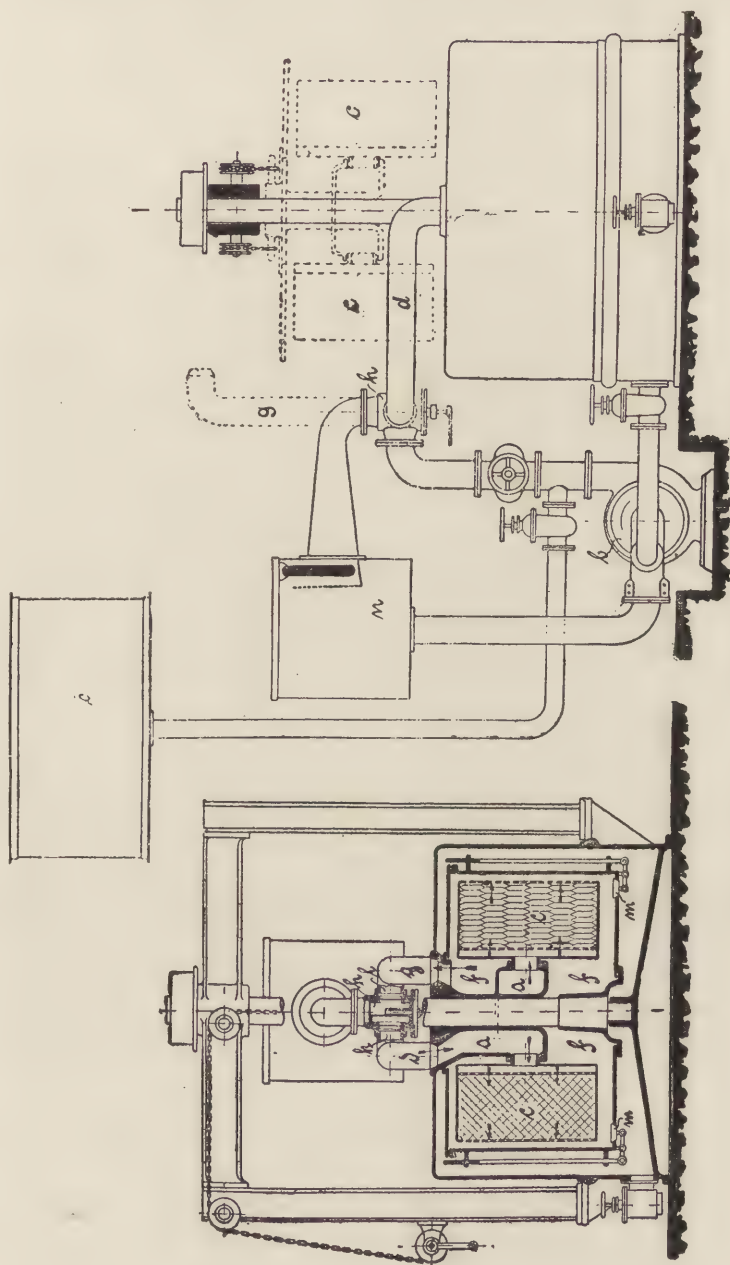


Fig. 68. Sectional View of Cohnen Centrifugal Dyeing Machine

they are swung up into the position indicated by the dotted lines after the dyeing, etc., have been completed, leaving the hydro-extractor free to rotate. These two pipes are connected by a three-way cock *h* which controls the direction of flow of the dye liquor and can be regulated at will — that is to say, the liquid entering first at *k* and leaving at *l* can, by simply turning this cock,

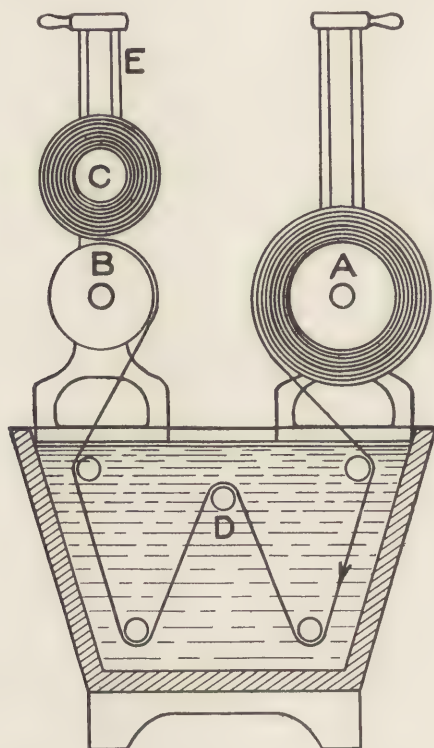


Fig. 69. Sectional View of Jig Dyeing Machine.

have its flow reversed, entering at *l* and leaving at *k*. The liquid then flows through the material from the outside. By this two-fold direction of flow more uniform results in the dyeing are obtained.

The dyeing being completed, the outlet valves *m* are opened and the hydro-extracting carried out in the usual manner.

Jig Dyeing Machines already referred to under the Basic Colors (See 170) are extensively used for dyeing cotton cloth in



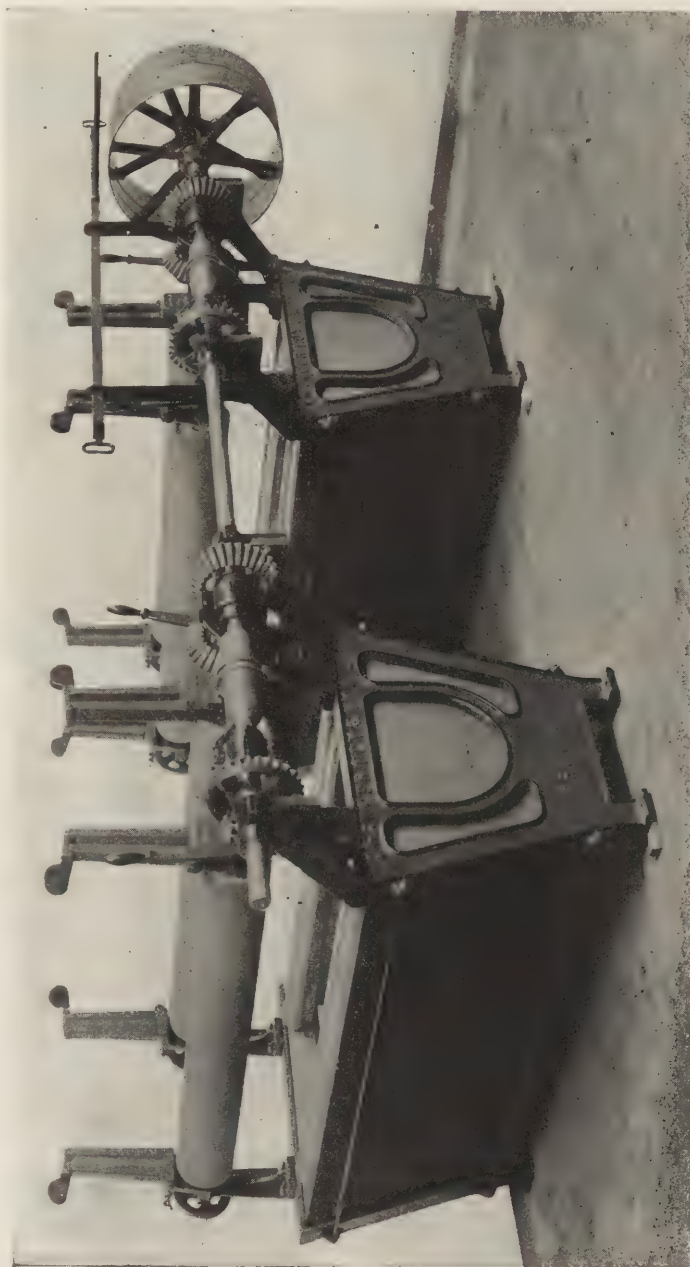


Fig. 70. Jig Dyeing Machines, Textile Finishing Machinery Co.

the open or full width with both the direct cotton and sulphur colors. A jig dyeing machine (See Figs. 69 and 70) consists of a dye vat D, and two fixed rollers A and B, worked by a series of gears. At the beginning of the operation the cloth to be dyed is smoothly wound upon one of the fixed rollers A, and then passed through the dye vat in the direction indicated by the arrowhead onto the second fixed roller B. The cloth is then passed through the dye liquor back on to A, and so on back and forth until the dyeing is completed. At the end of the operation the cloth is wound onto the movable roll C, which sets into the slotted upright E. Ten to fifteen pieces of cloth are sewn together in a continuous piece and passed through the dye liquor at the rate of about one minute per piece. The vat portion D should be as small as possible, and usually holds from thirty-five to forty-five gallons of liquor.

*Cotton warps* are usually dyed in a machine similar to that represented at Fig. 71. It consists of a dye vat provided with a series of rollers within the vat, about which the *chains of warp* (See 118, Part II.) pass several times, and a pair of squeeze rolls, between which the warp leaves the machine.

The single tub, Fig. 72, sometimes called a *Scotch dye tub*, is used largely for the dyeing of basic and direct cotton colors, but for sulphur colors, several tubs (two, three, and sometimes four) are combined together, as in Fig. 71. In a machine of this construction, eight or ten chains pass through, parallel to each other. Similar machines are used for washing the warp, and oftentimes the last compartment is used as a wash box. In this latter case, the warp goes directly to the drying cans (See Fig. 51, Part II.) upon leaving the apparatus. For sulphur colors the upper series of rolls should be kept below the surface of the liquor, as in Fig. 71.

**196. Properties of the Sulphur Colors.** The most valuable property of the sulphur colors is their fastness to light, washing and acids. Their fastness to chlorine and bleaching, however, is in most cases not good.

Nearly all the sulphur colors are insoluble in water, but dissolve readily in a solution of sodium sulphide, and as already

explained, copper vessels must not be used for their solution.

Most of the sulphur colors contain more or less alkaline sulphide, and for this reason are more or less deliquescent. They must, therefore, be stored in closed containers, and in a dry room away from steam.

The shades produced by the sulphur colors are mostly of a dull character, and blacks, browns, dark blues, dark greens, and dull yellows; also various compound shades of these, such as drabs, slates, olive, and greys predominate. Sulphur yellows and greens as a rule do not equal the other sulphur colors in fastness. As yet no bright sulphur reds\* have been prepared.

**197. List of Principal Sulphur Colors.** The list of sulphur colors is not larger, and the following includes the principal ones.

#### BLACKS.

Immedial Black V, FF, G, N B, N G, N R T, and N F

Sulphur Black T T G, T B, B B, and A.

Thiogene Black N A, N B, T, M, M R, M M, 2 B and 4 B.

Katigene Black T, S W, T G, 2 B, and S W R.

Tetrazo Sulphur Black 2 B, and R.

Thional Black	Buffalo Thiol Black G. B.	Melanogen Black
Vidal Black	Clayton Fast Black	Pyrogene Black
Kryogene Black	Cross Dye Black	St. Denis Black
Auronal Black	Direct Sulpho Black	Sufanil Black
Autogene Black	Eclipse Black	Mercaptol Black

#### BLUES.

Immedial Blue and C.	Thiogene Dark Blue	Katigene Indigo
Immedial Indone	Tetrazo Sulphur Indigo B.	Melanogen Blue
Immedial Sky Blue	Direct Cross Dye Blue	Katigene Chrome Blue
Sulphur Blue L.	Eclipse Blue	
Thiogene Blue B.	Vidaline Blue	Pyrogene Blue
Katigene Blue B.	Kryogene Blue	Sulphogene Blue

#### BROWNS.

Immedial Brown	Tetrazo Sulphur Brown	Katigene Brown
Immedial Bronze	Thiogene Brown	Katigene Khaki
Immedial Catechu	Thion Brown	Cachou de Laval S.
Sulphur Brown	Thional Bronze	Thio Catechine
Sulphur Bronze	Thional Brown	Thiogene Khaki
Sulphur Cutch	Vulcan Brown	Vidaline Brown

#### GREENS.

Immedial Green	Katigene Green	Sulphur Green
Immedial Olive	Katigene Olive	Thion Green
Alizarine Green K. O.	Kryogene Olive	Thional Green
Eclipse Green	Pyrogene Green	Vidaline Green
Eclipse Olive	Pyrogene Olive	

\*Note—Thiogene Rubime O, recently introduced by the H. A. Metz Co., is the nearest approach to a sulphur red. It is, however, too much upon the violet to be called a red.

## YELLOWS.

Immedial Yellow	Immedial Orange	Tetrazo Sulphur Yellow
Cross Dye Yellow	Kryogene Yellow	Thiogene Orange
Eclipse Phosphine	Katigene Yellow	Thiogene Gold Yellow
Eclipse Yellow	Pyrogene Yellow	

## MISCELLANEOUS COLORS.

Cross Dye Drab	Eclipse	Pyrogene Gray
Eclipse Corinth (Reddish Brown)	Immedial Bordeaux	Thiogene Violet
Sulphur Corinth		

As with the direct cotton colors, dyestuff concerns have adopted certain trade names for the sulphur colors, some of which are as follows :

Immedial Colors,	Cassella Color Co.
Katigene Colors,	Farbenfabriken Co.
Sulphur Colors,	Berlin Aniline Works.
Thiogene Colors,	Meister Lucius and Bruning. (H. A. Metz.)
Kryogene Colors,	Badische Anilin & Soda Fabrik. (Kuttroff, Pickhardt & Co.)
Thional Colors,	Levinstein & Co., (Thos. Leyland & Co.)
Eclipse Colors,	Geigy Color Co.
Tetrazo Sulphur Colors,	American Dyewood Co.
Pyrogene Colors,	Klepstein.
Autogene Colors,	} Sykes & Street.
Vidaline Colors,	
St. Denis Colors.	

## THE ARTIFICIAL MORDANT COLORS.

**198. General Consideration.** Under this head we will include only those artificial coloring matters which cannot be applied without the use of some metallic mordant. The *Natural Mordant Colors* have already been described in Part III (Nos. 144 to 164) and the *Mordant Acid Colors*, sometimes included under this head, will be described later (See No. 204.)

The true metallic mordant colors cannot be permanently fixed upon cotton, wool and silk or in fact upon any textile fiber, except in conjunction with metals.\* As a rule the metals are fixed upon the fiber as insoluble oxides or hydroxides (mordants) previous to the application of the dyestuff.

During the dyeing process the mordant dyestuffs, which con-

\*The processes of applying mordants and their chemical nature are fully discussed in Part III, Nos. 128 to 132 inclusive.



tain either hydroxyl ( $-OH$ ) or carboxyl ( $-COOH$ ) groups in their composition, react with the mordants in much the same manner as acids react with bases to form salts, the resulting salt-like compounds being insoluble color lakes, which become fixed upon and within the body of the fiber, which is thus permanently colored. During this reaction, which takes place between dyestuff and mordant, the hydrogen atoms of the hydroxyl and carboxyl groups are replaced by the metal of the mordant.

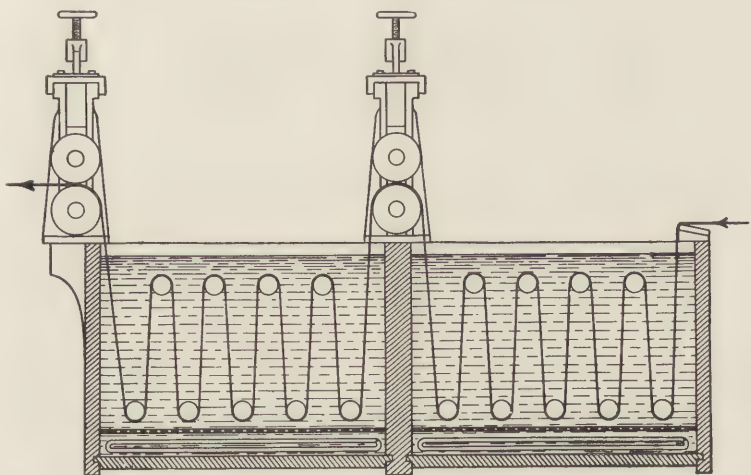


Fig. 71. Dye Tub for Chain Warps.

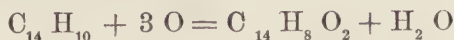
When classified according to composition there are four classes of Artificial Mordant Colors.

- (1) Anthracene Derivatives (the Alizarines.)
- (2) Naphthalene. “
- (3) Pyrogallol “
- (4) Nitroso Coloring Matters.

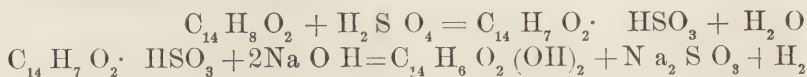
(1) THE ANTHRACENE DERIVATIVES are by far the most important group of metallic mordant colors. This group includes *alizarine* and its derivatives, and for this reason they are commonly called the alizarine colors.

Alizarine  $C_{14}H_6O_2(OH)_2$  is produced as follows from anthracene, one of the solid hydrocarbons derived from coal tar.

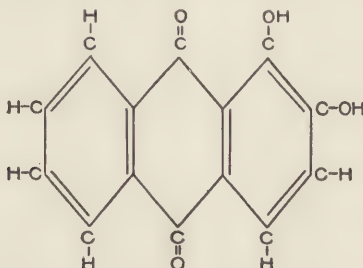
Anthracene  $C_{14}H_{10}$  is oxidized when the following reaction takes place.



The resulting compound anthraquinone  $\text{C}_{14}\text{H}_8\text{O}_2$  is then sulphonated with concentrated sulphuric acid and the resulting sulphonate fused with caustic soda. The equations representing the reactions are as follows:



The following represents the structural formula of alizarine.



Alizarine therefore contains two hydroxyl groups, and is known chemically as dihydroxy anthraquinone. It occurs naturally as the active coloring principle of madder and was first prepared artificially by Graebe and Liebermann in 1868.

Like many of the metallic mordant colors, alizarine is polygenetic \* and gives different color lakes with different metals.

Thus alizarine gives

Red	with Aluminium	Mordants.
Orange Reds	"	Tin "
Wine Color	"	Chromium "
Purplish Black	"	Iron "
Yellowish Brown	"	Copper "
Reddish Brown	"	Zinc & Nickel "

Note. Coloring matters are sometimes classified as *monogenetic* and *polygenetic*.

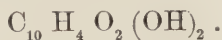
Monogenetic colors are those capable of producing only one color, or at the most only varying hues of the same color, regardless of the manner of application, or the mordants used. Thus auramine always produces a yellow; methylene blue produces a blue and acid ponceau produces a red.

Polygenetic colors are those capable of producing entirely different colors depending upon the mordants used. Alizarine, cochineal and many of the mordant dyestuffs are polygenetic.

Alizarine is a stable compound and although mild oxidizing agents have no action upon it, powerful oxidizing agents like concentrated sulphuric and nitric acids react with it producing a number of valuable derivatives. Thus purpurin, anthrapurpurin, flavopurpurin, and anthracene brown are all trihydroxy anthraquinones.

The Alizarine Bordeauxs are tetra-hydroxy anthraquinones. Alizarine Cyanine R is a penta-hydroxy anthraquinone. In addition to these there are the *nitro sulphonic acid* and *amino derivatives*.

(2) NAPHTHALENE DERIVATIVES. The most important mordant color derived from *Naphthalene* is Alizarine Black S. In structure it bears the same relation to Naphthalene that Alizarine does to Anthracene. For this reason it is sometimes called Naphthazarin. Its formula is



(3) THE PYROGALLOL DERIVATIVES are more or less directly related to pyrogallol (pyrogallic acid)  $\text{C}_6 \text{H}_3 (\text{OH})_3$ . They are fewer in number and of less importance than the anthracene derivatives.

(4) THE NITROSO COLORING MATTERS are produced by the action of nitrous acid upon various phenols, and contain the nitroso or (-NO) group.

**199. Application of the Mordant Colors to Wool.** The mordant colors are largely used in wool dyeing when it is desired to produce very fast colors. The colors produced (except with Alizarine and Alizarine Yellow upon aluminium or tin mordants) are of a dark and subdued character. Blacks, dark blues, dark greens, browns, garnets, dull reds and compound shades of these predominate.

In every case some metallic mordanting principle must be used in conjunction with the dyestuff. The mordant may be applied in three different ways.

I. Previous to the dyeing.

II. At the same time as the dyeing.

III. After the dyestuff has been applied.

The first method is by far the most important, the second being applicable only with some of the natural mordant colors and

some alizarine reds and yellows. The third method is seldom if ever used for the true mordant colors, although extensively used with the mordant acid colors.

Chromium mordants are used almost entirely, except for reds, pinks, and bright yellows, aluminium and sometimes tin mordants being used for these. With some of the nitroso colors iron mordants are largely used.

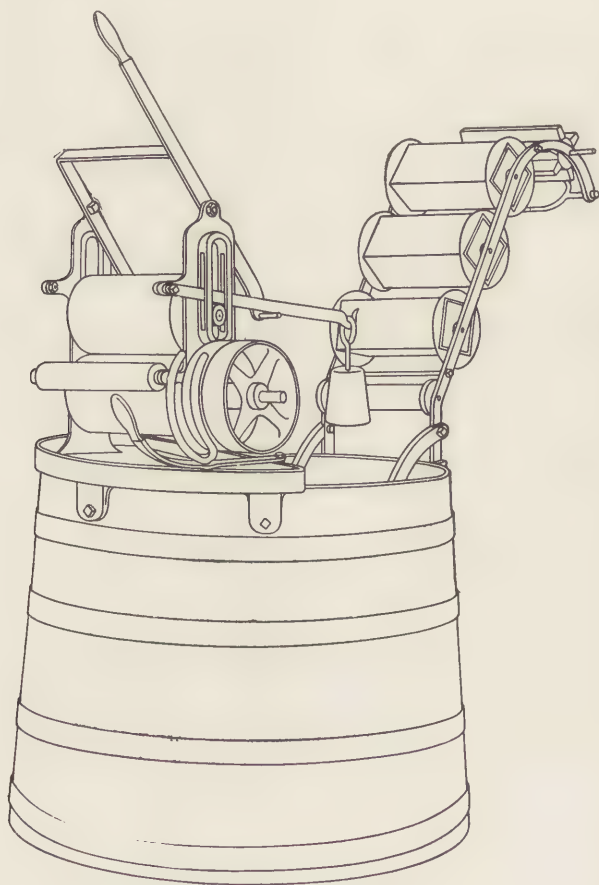


Fig. 72. Scotch Dye Tub.

The whole subject of mordants has been fully discussed, both as to principle and methods of application, and the student is referred at this time to Part III for details. The following general statement will therefore suffice.



**Mordanting Process.** The wool, which should be well scoured and washed, is mordanted by boiling from one to two hours, depending upon the nature of the material, in a bath containing the mordanting principle,\* (usually potassium bichromate 1 to 4%) and some mordanting assistant, † (usually potassium bitartrate or lactic acid  $1\frac{1}{2}$  to 3%) during which time there is a gradual dissociation of the mordanting principle and slow deposition of the mordant proper upon the fiber.

**Dyeing Process.** The chromium mordanted material (wool fiber) is thoroughly washed and then dyed in a fresh bath. When possible the mordanting material is not allowed to dry between the mordanting and dyeing. The dye bath is prepared with:

Mordant Color.	5 to 15% paste color or 1 to 5% dry powder color.
Acetic Acid.	A slight excess above the amount necessary to convert the calcium salts present in the water into calcium acetate.

The material is entered into the dye bath at ordinary temperature. The temperature is slowly raised to the boil, and the dyeing continued at a boil from  $1\frac{1}{2}$  to, in some cases,  $2\frac{1}{2}$  hours, this long boiling being necessary to bring about the complete reaction of mordant with dyestuff and ensure the thorough fixation of the color lake upon the fiber.

The *acetic acid* is added chiefly to convert alkaline calcium salts present in the water into calcium acetate, as the former react with most of the alizarine colors to form calcium color lakes, the presence of which is detrimental to the best results when chromium mordants are used. A slight excess of acetic acid not only prevents any reaction of the calcium acetate thus formed, with dyestuff, but seems to be beneficial to the formation of the chromium color lakes. For ordinary water 1 lb. of acetic acid (30% acid) per 100 gallons of dye liquor is usually sufficient, but if the hardness exceeds  $5^{\circ}$ , 3 oz. should be added for each additional degree.

When too great an excess of acetic acid is added at the beginning of the dyeing, the color is absorbed too rapidly, and uneven dyeings are likely to be produced. To prevent such unevenness the *Badische Anilin and Soda Fabrik*, extensive manufacturers of alizarines, recommend the addition of ammonium acetate (with a very slight excess of ammonia) to the dye bath at the beginning

\* See No. 128.

† See No. 128-6.

of the dyeing. The slightly alkaline condition of the dye bath increases the solubility of the dyestuff, and prevents the rapid absorption of the color. As the temperature of the dye bath rises and it begins to boil, the excess of ammonia evaporates, the bath gradually becomes acid, and the union of dyestuff with mordant then takes place. Toward the end of the dyeing a slight excess of acetic acid is added to complete the absorption of the dyestuff and the fixation of the color lake.

When dyeing alizarine colors upon aluminum mordants the presence of calcium compounds is not as a rule detrimental, and in fact with alizarine red small amounts are necessary for the production of the best results. If the water is unduly hard, however, a small amount of acetic acid should be added.

The presence of iron compounds in the dye bath is very detrimental to the attainment of good results when dyeing alizarine reds upon aluminum mordants.

**200. Application to Cotton.** With the exception of alizarine upon an aluminum oil mordant for the production of the so-called "Turkey-reds", the alizarine colors are not extensively used in cotton dyeing, although largely used in cotton printing for the production of very fast colors.

**Alizarine-red or Turkey-red.** For many centuries cotton was dyed with madder (See No. 154) for the production of the so-called Turkey-reds, which possessed remarkable fastness to light, washing, dilute acids and dilute alkalies. Since the discovery of the method of manufacturing alizarine the artificial product has entirely replaced madder in the production of these reds.

The dyeing process which consists in fixing upon the fiber an alizarine - aluminium - calcium - oil color-lake has been experimented upon ever since the time of the ancients, and for this reason it is not at all strange that so many different processes exist for its application, but since the introduction of artificial alizarine the chemistry of these processes has been more thoroughly studied, with the result that they have been rendered simpler and fully as satisfactory, although as yet there is considerable variation in the detail of the methods used.

In general there are two different methods:

- (1) The Emulsion or Old Process.

## (2) The Turkey-red Oil or New Process.

The Emulsion process is by far the longer and consists of a great many tiresome operations, but when completed the reds produced possess greater fastness than those produced by the Turkey-red Oil process, although the latter claims greater brilliancy and can be completed in a much shorter time. These processes in outline are as follows.

## EMULSION OR OLD PROCESS

Operation 1. Boiling in 1° Tw. soda ash solution for 6 to 8 hours.

Operation 2. Treatment with rancid olive oil and soda ash solution, and is known as the *first greening*. The material is worked in this so-called *green liquor* at a temperature of 100° C, until thoroughly impregnated, and then dried at a temperature of 140° F.

Operation 3. *Second greening*. Repetition of Operation 2.

Operation 4. *Third greening*. Repetition of Operation 2.

Operation 5. *First white bath*. Consists in working the material in a 2° Tw. soda ash solution until thoroughly impregnated, then wringing and drying in the open air.

Operation 6. *Second white bath*. Repetition of Operation 5.

Operation 7. *Third white bath*. Repetition of Operation 5. The object of these white baths is to remove the excess of oil.

Operation 8. Steeping for twelve hours in a bath of clean water at 150° F., then wringing and drying. Sometimes a small quantity of soda ash is added to this bath.

Operation 9. *Mordanting and Aluming*. Consists in thoroughly working the material and then allowing it to steep for 24 hours in a bath made up with 4 parts of alum to 1 part of soda crystals, and standing at 8° Tw. Sometimes a small amount of stannous chloride (tin crystals) or aluminum acetate (red liquor) is added. After this operation the material is thoroughly washed.

Operation 11. *Dyeing*. This is carried out in a bath made up with 10 to 12 % Alizarine.

3 % Light Sumac Extract.

$\frac{1}{8}$  % Lime.

The material is entered cold, and worked until thoroughly saturated, when the temperature is raised slowly to a boil and the dyeing continued at a boil until the full shade is developed, which takes at least one hour.

Operation 12. *First Clearing*. Consists in boiling the material four hours with

3 % Soda Crystals.

3 % Soap.

Operation 13. *Second Clearing*. Consists in boiling two hours with

3 % Soap.

$\frac{1}{2}$  % Tin Crystals.

After washing and drying the process is completed. The resulting red varies slightly with the brand of alizarine used. This process takes from two to three weeks for completion.



## THE TURKEY-RED OIL OR NEW PROCESS.

When it was discovered that by saponifying castor oil with alkali or by sulphonating it with concentrated sulphuric acid, products soluble in water were formed, which could be fixed upon cotton in a single operation, the process of producing Turkey-red became very much simplified.

The Turkey-red oil process is in outline as follows:

Operation 1. *Thorough Bleaching.*

Operation 2. *First Mordanting.* Consists in working the material in a bath of

-or Aluminium Acetate 9° Tw.  
Basic Aluminium Sulphate 9° Tw.

until it is thoroughly and evenly penetrated, then squeezing and drying at 120° F. for 24 hours.

Operation 3. *First Oiling.* Consists in working the material until thoroughly penetrated in a bath made up with

1 part Turkey-red Oil  
9 parts Water,

and then quickly and thoroughly squeezing, and then drying at a temperature of 140° to 150° F. for 12 hours.

Operation 4. *Second Mordanting* which is carried out the same as the first mordanting (Operation 2).

Operation 5. *Chalking.* Consists in working the dried mordanted material in a bath made up with

$\frac{1}{2}$  part Chalk (Calcium Carbonate)  
100 parts Water

for  $\frac{1}{2}$  hour at a temperature of 85° to 105° F., and then washing in clean water.

Operation 6. *Dyeing.* The dye bath is made up with

6 to 15 % Alizarine Paste

and the necessary amount of water which should contain at least 5 parts Lime per 100,000 of Water.

The damp material is entered cold, and after working 20 minutes the temperature is slowly raised to 140 to 150° F. and the dyeing continued at that temperature for one hour, when it is washed, and then squeezed or hydro-extracted.

Operation 7. *Second Oiling.* This is carried out in the same manner as the first oiling (Operation 3.)

Operation 8. *Steaming.* This consists in steaming for two or three hours at a pressure of from 7 to 15 lbs. and then thoroughly washing.

Operation 9. *Brightening.* This, the last operation, consists in boiling the material for  $\frac{1}{2}$  to 1 hour in a soap solution made up with

1 part Soap  
200 parts Water.

After the boiling the material is dried and finished.

To shorten the process Operations 7 and 8 are sometimes omitted.

In **Calico printing** the alizarine colors are largely used when



it is desired to make very fast prints. They are applied by the process known as *steam printing*, which consists in mixing the dyestuff and mordanting principle together with some thickener, and printing the color paste thus formed upon the cloth in a printing machine. The cloth is then dried and passed through a steam chamber, where the high temperature and moist atmosphere cause a decomposition of the mordanting principle, and the mordant thus liberated reacts with the alizarine color to form a color lake. The cotton cloth should be previously bleached, and then prepared by working in a solution of Turkey-red oil, and then drying. Several recipes for such printing pastes will serve as examples of many others.

- (A) 100 lbs. Alizarine Red Printing Color.  
15 lbs. Alizarine Paste.  
9½ lbs. Acetate of Calcium 15° Tw.  
9 lbs. Sulphocyanide of Aluminium 32° Tw.  
8½ lbs. Oxalate of Tin 25° Tw.  
58 lbs. \*Starch Thickener.
- (B) 100 lbs. Claret Red Printing Paste.  
10 lbs. Alizarine Paste.  
4 lbs. Acetate of Calcium 15° Tw.  
5 lbs. Acetic Acid 9° Tw. (30%).  
9 lbs. Acetate of Chromium 32° Tw.  
72 lbs. \*Starch Thickener.
- (C) 100 lbs. Violet Printing Color.  
5 lbs. Alizarine Paste (Blue Shade.)  
7½ lbs. Calcium Acetate.  
25 lbs. Acetic Acid 9° Tw.  
2½ lbs. Acetate of Iron 23° Tw.  
60 lbs. \*Starch Thickener.
- (D) 100 lbs. Alizarine Blue Printing Color.  
20 lbs. Alizarine Blue S Paste.  
5 lbs. Acetate of Chromium 32° Tw.  
75 lbs. \*Starch Thickener.
- (E) 100 lbs. Alizarine Green Printing Paste.  
20 lbs. Alizarine Green S Paste.  
5 lbs. Chromium Acetate 32° Tw.  
75 lbs. \*Starch Thickener.

\*Note. The starch thickener referred to in the above recipes is made up as follows:

- 2 lbs. Wheat Starch.  
5 lbs. Gum Tragacanth Paste (60 to 1000 water).  
1¼ lbs. Olive Oil.  
2 gallons water.

The mixture is stirred while cold, then boiled till a uniform paste is formed, and the mass kept stirred till cold, and finally passed through a fine sieve.

After printing with the above colors, the cloth is well dried and then steamed for one hour at  $7\frac{1}{2}$  lbs. pressure, or for two hours without pressure. After steaming the prints are washed and then soaped for  $\frac{1}{4}$  hour at a temperature of about  $120^{\circ}$  F. With Alizarine red the cloth should be worked several minutes in a chalk bath before soaping.

**201. Application to Silk.** The mordant colors can be applied to silk, but are seldom used with this fiber, unless fastness to soap and washing are desired. Aluminium mordants are used for reds and bright shades of yellow and orange, iron mordants for blacks, and chromium mordants for other colors.

With *aluminium mordants* the process is as follows:

Prepare the mordanting bath with

175 parts water (Free from iron)

10 parts Alum

1 part Soda Crystals

and allow it to boil until it becomes perfectly clear.

Work the "boiled off" silk in this bath for one-quarter to one-half hour, then allow it to steep (completely under the surface of the liquor) for twelve hours. It is then wrung, or hydro-extracted, and without washing entered into a fixing bath of Silicate of Soda  $1^{\circ}$  Tw. It is worked in this for fifteen minutes, then thoroughly washed in running water and should then be dyed without drying in a bath made up with:

Dyestuff. Necessary amount to produce shade.

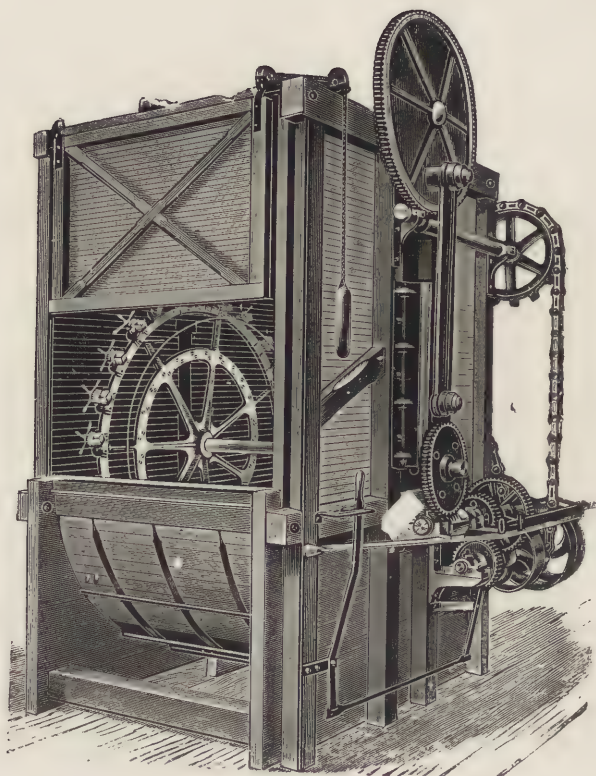
Water and "Boiled Off" liquor in proportion of 5 parts to 1.

In the production of alizarine reds, the dyebath is just neutralized with acetic acid, and, unless the water is very hard, a small amount of calcium acetate should be added. The silk is entered into the dyebath at  $80^{\circ}$  to  $90^{\circ}$  F., worked at this temperature for  $\frac{1}{4}$ -hour, brought very slowly to a boil and then dyed at a boil for about one hour. It is then washed, soaped at  $140^{\circ}$  F., and brightened by working in dilute acetic acid.

With *chromium mordants* the process is the same as for aluminium mordants, with the exception that chromium chloride solution  $32^{\circ}$  Tw. is used in place of alum and soda crystals.

**202. Properties of the Mordant Dyestuffs.** Most of the mordant dyestuffs are either insoluble or only slightly soluble in water, and are sold in the form of pastes which contain 20% of





SILK SKEIN DYEING MACHINE, SHOWING DYE-WHEEL  
IN WORKING POSITION

Klander-Weldon Dyeing Machine Co.



the coloring matter in an extremely finely-divided condition, and 80% water. A few of them are soluble in water, and are sold as dry powders. These powdered dyestuffs can be readily dissolved in water, except those that are bisulphite compounds, which should be dissolved in cold water, as hot water decomposes them. As a rule, the solubility of the mordant colors increases in alkaline solutions and diminishes in acid solutions.

**Note.** Great care must be taken when these pastes are removed from their containers, otherwise, one may draw nearly all water and the strength of the paste will increase rapidly as the bottom is reached. For this reason the head of the barrel should be removed, and the contents thoroughly stirred with a wooden stick before each removal of dyestuff.

As a class, the mordant dyestuffs are the fastest colors known, and their fastness to light, washing, soaping, alkalies, acids, perspiration, and in fact, nearly all of the color-destroying agencies, have given them an unquestioned standing, and have led many armies, navies and railroad companies to adopt them for the coloring of their uniforms. They are extensively used in the coloring of the best grades of suitings and overcoat cloths. Their properties are sufficiently alike in most cases to allow of their being used in the same dyebath, and, therefore, in the production of innumerable compound shades.

**203. List of Important Mordant Colors.** The following is a list of the most important mordant colors:

#### REDS.

Various brands of Alizarine, Purpurin, Anthra-Purpurin and Flavo-Purpurin, with aluminium mordant for bright reds, and with chromium mordants for dark reds, claret reds, and bordeaux reds.

#### YELLOWS.

Alizarine Yellows  
Anthracene Yellows  
Azo Chromine  
Galloflavine  
Mordant Yellow.

#### BLACKS.

Alizarine Blacks.

#### BROWNS.

Alizarine Browns  
Anthracene Browns  
Gambine.

#### ORANGES.

Alizarine, with tin mordants  
Alizarine Orange.

#### BLUES.

Alizarine Blues  
Anthracene Blues  
Alizarine Indigo Blue.

#### VIOLET.

Alizarine, with iron mordants  
Chrome Violet  
Alizarine Violet.

#### GREENS.

Alizarine Green  
Alizarine Dark Green.

**Note.** Unfortunately, there has been such laxity displayed by certain dyestuff manufacturers and dealers in the naming of the mordant

acid colors (See No. 204) that it is often impossible to tell by the name whether a dyestuff is a true mordant color or a mordant acid color. Again, the desirability of alizarine colors is so generally known that unscrupulous dealers sometimes use the term alizarine in connection with a color when it belongs to neither of the above classes, but is simply an acid color. The term has sometimes been applied to direct cotton colors.

#### THE MORDANT ACID COLORS.

**204. General Consideration.** The group of dyestuffs, known as the *mordant acid colors*\* is intermediate in character between the *acid colors* and the *mordant colors*. They resemble acid colors in that they may be dyed directly upon wool in an acid bath, and at the same time resemble the mordant colors in that they may be dyed upon metallic mordanted wool.

**In chemical composition**, these dyestuffs vary considerably, thus many of them are azo compounds combined with salicylic acid; the cloth reds are azo derivatives of benzene or toluene combined with naphthalene derivatives, while certain others are sulphonic acid compounds of anthracene derivatives. The most important chemical characteristic of composition is the presence of either hydroxyl or carboxyl groups, for it is these groups that render it possible for them to unite with mordants to form color lakes.

Of recent years, the number of mordant acid-colors has greatly increased, and at the present time they are receiving much attention in wool dyeing, having replaced the mordant colors to a certain extent. Their popularity lies in the ease with which they may be applied, and the fact that an after-treatment with some mordanting principle converts them into color lakes possessing excellent fastness to light, acids, washing and soaping.

**205. Application of Mordant Acid-Colors to Wool.** The first step in applying the mordant acid-colors is the same as the dyeing of acid colors upon wool, *i. e.*, in a bath containing

Dyestuff	Necessary amount.
Sodium Bisulphate	10%.
or Glauber's Salt	10 to 15%.
Sulphuric Acid	3 to 4%.

\*Note. These dyestuffs are sometimes called the acid-mordant colors, but, as this name might imply that they were applied upon an acid mordant, the term mordant acid-colors is preferable, as it conveys the correct idea that they are acid colors of a mordant character

Enter the material at 140° F., bring gradually to the boil and dye at a boil until the color is exhausted from the dyebath. This should occur in from 45 minutes to 1 hour. In every case, there must be sufficient acid present to bring about as complete an exhaustion as possible, for any excess above this amount is detrimental, as it has a tendency to hold some of the dyestuff in solution.

After the dyeing, the material is raised from the dyebath and the mordanting principle (previously dissolved) added. After thoroughly stirring the bath, the material is re-entered and again boiled for  $\frac{1}{2}$  to  $1\frac{1}{2}$  hours, depending upon the nature of the dyestuff used. In case the dyebath is not exhausted of color, a new bath should be used for the after-treatment.

In nearly every case, the mordanting principle used is *potassium* or *sodium bichromate*, in the proportion  $\frac{1}{2}$  to 4%, depending upon the amount of dyestuff used and to some extent upon its character.

With some of these colors, *e. g.*, chromogen I, and the chromotropes, it is absolutely necessary that there shall be an oxidizing action during the after-treatment, in which case potassium or sodium bichromate must be used. With certain others an oxidizing action is detrimental, and with these either chromium fluoride, chromium chloride, chrome alum, or copper sulphate is used as the mordanting principle.

In some cases  $1\frac{1}{2}$  to 3% of *lactic*, or *formic acids*, may be added to advantage in addition to the mordanting principle, their action being the same as that of mordanting assistants during a regular mordanting process.

These dyestuffs may, in most cases, be applied equally well upon mordanted wool, but as this method is more expensive, and the results obtained are no better, it is seldom done.

As a rule, the color of the dyed material is greatly changed during the after-treatment. Thus the chromotropes give varying shades of red, which develop into navy blues and blacks, and certain of the browns and blues are of a yellow color before the after-treatment.

Many of the mordant acid-colors are useful as ordinary acid colors, but in nearly every case the fastness is greatly increased by the after-treatment.



## 206. List of Important Mordant Acid-Colors.

## REDS.

Acid Alizarine Claret  
 Acid Alizarine Red  
 Alizarine Red, S, 2S & 3S  
 Anthracene Red  
 Anthracene Chrome Red  
 Anthracyl Red  
 Cloth Reds (All brands.)  
 Chrome Red  
 Chrome Bordeaux  
 Emin Red  
 Milling Reds (All brands.)  
 Palatine Chrome Red B  
 Salicine Red.

## ORANGES and YELLOWS.

Alizarine Yellow GG., GW, R & RW  
 Alizarine Azo Yellow  
 Anthracene Yellow BN, C, & GG  
 Aurotine  
 Chrome Fast Yellow  
 Chrome Yellow D  
 Cloth Yellow  
 Cloth Orange  
 Crumpsall Yellow  
 Diamond Yellow  
 Diamond Flavine  
 Fast Mordant Yellow  
 Milling Yellow  
 Mordant Yellow GGR, R & 3R  
 Milling Orange  
 Resoflavin  
 Salicine Yellow.

## BLUES.

Acid Alizarine Blues  
 Alizarine Sky Blue  
 Alizarine Saphirol  
 Alizarine Celestol  
 Anthracene Blues  
 Anthraquinine Blue  
 Anthracyl Blue  
 Brilliant Alizarine Blue  
 Chrome Blue

The Chromotropes  
 Cyananthrol  
 Gallanilic Indigo.

## VIOLETS.

Alizarine Heliotrope 2B  
 Anthracene Chrome Violet B  
 Anthraquinine Violet  
 Fast Acid Violet  
 Gallanic Violet.

## BROWNS.

Acid Alizarine Browns  
 Acid Chrome Browns  
 Anthracene Chrome Browns  
 Chrome Browns  
 Cloth Browns  
 Domingo Browns  
 Diamond Browns  
 Sulphamine Browns.

## GREENS.

Acid Alizarine Green  
 Alizarine Dark Green  
 Alizarine Cyanine Green  
 Brilliant Milling Green  
 Chrome Green  
 Diamond Green  
 Domingo Green  
 Naphthol Green B.

## BLACKS.

Acid Alizarine Blacks  
 Acid Chrome Blacks  
 Alizarine Black WR  
 Alizarine Chrome Blacks  
 Alizarine Fast Black T  
 Anthracene Acid Blacks  
 Anthracite Black B  
 Chrome Blacks  
 Crown Blacks  
 Diamond Blacks  
 Palatine Chrome Blacks.



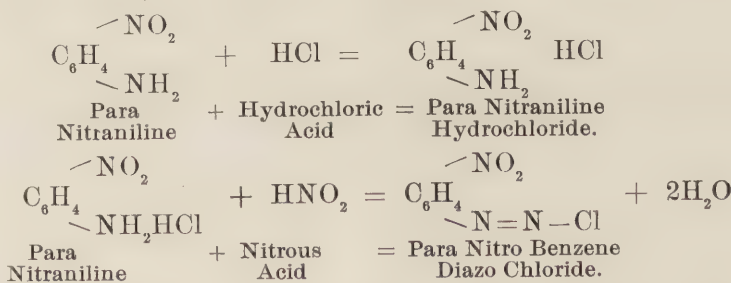
## THE INSOLUBLE AZO COLORS.

**207. General Consideration.** The insoluble azo colors, as the name implies, are a group of insoluble coloring matters of the azo type. Their insolubility in water renders them non-applicable by any of the methods already described, but fortunately the nature of the process of their formation is such that they may be produced directly upon the fiber.

Although many of these insoluble azo colors may be produced, only two are much used; the so-called *para nitraniline* and the *alpha naphthylamine reds*. These have been extensively applied in cotton dyeing during the past ten years, the former having replaced Turkey-red to a certain extent.

The colors of this class are sometimes known as *developed colors* because they are developed during the process of application; as *ingrain colors* because they are formed, as it were, within the grain of the fiber; and as *ice colors* because ice is often used to produce a low temperature during their application.

**208. Chemistry of Process.\*** When an aromatic amine (substituted ammonia) is neutralized with one of the common mineral acids†, and then allowed to react with nitrous acid in a cold and slightly acid solution, it is converted into a diazo compound. Thus with para nitro aniline or para nitraniline, as it is called for short, the reaction is as follows:

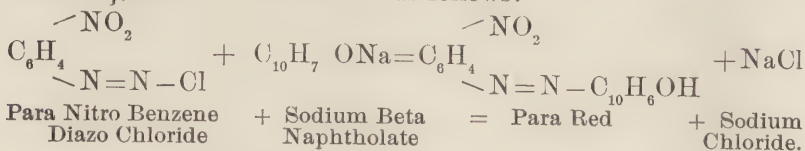


When certain diazo compounds or salts react with certain phenols, naphthols, or their derivatives, chemical combination takes place with the formation of insoluble azo coloring matters.

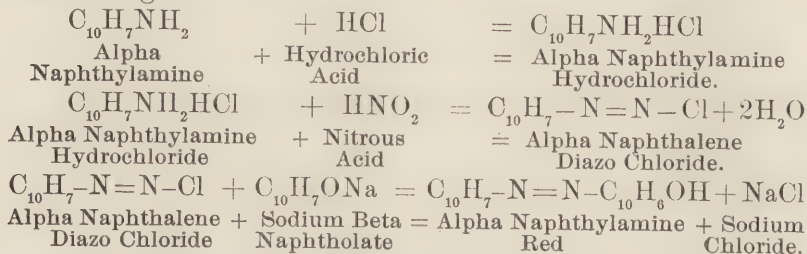
\*Note. The chemistry of the formation of the insoluble azo colors cannot be readily understood except by students of organic chemistry, the writer, however, has endeavored to make the process as clear as possible in the summary which follows the explanation of its chemistry.

†Note. The common mineral acids are sulphuric, nitric, and hydrochloric acids. The latter is most frequently used in this connection.

Thus when para nitro benzene diazo chloride reacts with sodium beta naphtholate, the compound formed is a bright red insoluble coloring matter or pigment, known as para red. The equation which represents the reaction is as follows:



If alpha naphthylamine, another aromatic amine, be neutralized and allowed to react with nitrous acid in the same manner and then combined with beta naphthol, the so-called alpha naphthylamine red is produced. The equations representing the reaction being as follows:



**Summary.** In other words certain organic compounds known as substituted ammonias or amines when neutralized by acids are converted into salt-like compounds, which react with nitrous acid in cold acid solution to form diazo compounds or diazo salts. The carrying out of this reaction is known as the *diazotising process*.

These diazo salts are soluble in water and when their solution is brought together with the solutions of the sodium compounds of certain phenols and naphthols, chemical union takes place with the formation of insoluble azo coloring matters which are precipitated in a finely divided condition.

**209. Application.** The insoluble azo colors are extensively used for dyeing and printing cotton fabrics; to a less extent for dyeing cotton yarn; and to a very limited extent for dyeing raw or loose cotton. They cannot be applied satisfactorily to animal fibers, as one step in the process requires the use of a strongly alkaline solution.

**Theory.** The phenols and naphthols used readily dissolve in concentrated caustic soda solution, forming sodium salts which are

soluble in water. When textile material is padded with one of these solutions, *e. g.*, with one of sodium beta naphtholate, it permeates the fiber, and when the material is dried the naphtholate remains upon the surface and within the body of the fiber.

When the material thus prepared is passed through a solution of the diazo salt, *e. g.*, para nitro benzene diazo chloride, this solution is rapidly absorbed by the fiber, and chemical union, as explained in Paragraph 208, takes place. The insoluble azo coloring matter, which in this case would be para nitraniline red, is formed wherever the naphtholate was deposited.

**Practice.** The process of application can be best considered under the three following heads, or steps:

- (1) Preparation of the Diazo Bath.
- (2) Preparation of the Cloth.
- (3) Dyeing (Developing or Coupling).

#### PREPARATION OF THE DIAZO BATH.

This consists in converting the aromatic amine, or substituted ammonia, into one of its soluble diazo salts (usually the chloride), and then holding it in solution in a suitable bath until ready to be used in the third step of the process.

The compounds used in its preparation are the aromatic amine, sodium nitrite, hydrochloric acid, sodium acetate, ice, and water.

The *aromatic amine*, or *substituted ammonia*, is usually para nitraniline or alpha naphthylamine. These are for the production of reds, and should be used in sufficient quantity to give the desired depth of color.

The *sodium nitrite* is used in sufficient quantity to liberate enough nitrous acid to carry out the diazotising process and convert the amine used into the diazo salt.

The *hydrochloric acid* is used for three purposes: first, to neutralize the amine; second, to liberate nitrous acid from the sodium nitrite; and third, to keep the bath decidedly acid, for in this condition the bath will keep better. The hydrochloric acid should therefore be used in about three times the quantity necessary to neutralize the amine.

The *sodium acetate* is added to the diazo bath just before it is to be used, in order that it may react with the excess of hydrochloric acid present, to form sodium chloride and liberate free



acetic acid, hydrochloric acid having been found to be detrimental to the best results if present during the dyeing. The sodium acetate should be added in slight excess of the amount necessary to react with the free hydrochloric acid present.

The ice is used to keep the bath at a low temperature as diazo salts are extremely unstable and many of them rapidly decompose even at ordinary temperature, while all of them are converted into entirely different compounds at still higher temperature. The use of ice is necessary in the Summer time, but in cold weather it may be omitted if the temperature of the diazo bath falls below 50° F. In general the colder the bath during the diazotising process the more stable the diazo compounds formed.

The preparation of the diazo solution requires considerable experience and great care, but strict adherence to the following directions should be followed by satisfactory results.

*Preparation of Diazotised Para Nitraniline:*

2½ lbs. Para Nitraniline

7 lbs. Hydrochloric Acid 36° Tw.

are boiled with

1½ gallons Water

until complete solution takes place, then the solution is poured slowly into

8½ gallons of Cold Water, (or enough to make up to 10 gallons)

and constantly stirred so that the yellow crystalline precipitate that forms will be as finely divided as possible. Then add

1 lb. 6 ozs. Sodium Nitrite

dissolved in

1 gallon Cold Water

as quickly as possible, stirring thoroughly. Allow the bath to stand 15 minutes, when the diazotisation will be complete.

Just before using, the excess of hydrochloric acid should be neutralized by adding

5½ lbs. of Sodium Acetate

dissolved in

1 gallon of Water.

*Preparation of Diazotised Alpha Naphthylamine.*

This may be prepared in the same manner as the diazotised para nitraniline with the exception that

2⅔ lbs. of Alpha Naphthylamine

should be taken and a little more water used in its solution.



## PREPARATION OF MATERIAL.

Previous to the dyeing, the material, if cloth, is prepared with beta naphthol, by passing through a padding machine, and then dried by passage through a hot flue, upon a tentering frame, or by passing over drying cans well wrapped with cotton cloth; or if yarn, by working in the sodium beta naphtholate solution (using rubber gloves) then wringing, hydro-extracting and drying.

The padding liquor is prepared as follows:

- 2 $\frac{1}{4}$  lbs. Beta Naphthol
- 2 lbs. Caustic Soda, dissolved in a little water.
- 4 $\frac{1}{2}$  gallons Hot Water
- 1 gallon Turkey-red oil

are dissolved together.

When solution is completely cool, make up to about 12 gallons with cold water.

No more padding liquor should be made than can be used the same day, for it does not keep well.

## DYEING. ALSO KNOWN AS DEVELOPING AND COUPLING.

This consists in passing the material, prepared with beta naphthol, in a perfectly dry condition through the diazo solution, then giving it a short exposure to the air in order to bring about complete development, and then thoroughly washing.

This process may be carried out in an apparatus, a cross section of which is shown in Fig. 73. The beta naphthol prepared cloth is passed through the color box A, into which the cold diazo solution is constantly fed, then between a pair of squeeze rolls. After passing a short distance through the air in order that the color may fully develop, the cloth passes through the spray washer B, the soap bath C, and the final rinsing box D, when it is ready to be dried and finished.

**210. Properties of Para Nitraniline and Alpha Naphthylamine Reds.** Para Nitraniline Red on cotton is much faster than any of the direct cotton reds of similar character; and as regards fastness to light is excelled only by Turkey-red. Para red is much faster to the action of chlorine than Turkey-red, but not as fast to boiling alkaline solutions, or steaming. Para red is affected by boiling with acids, and the action of copper salts changes it to a tobacco brown. It has the advantage of being

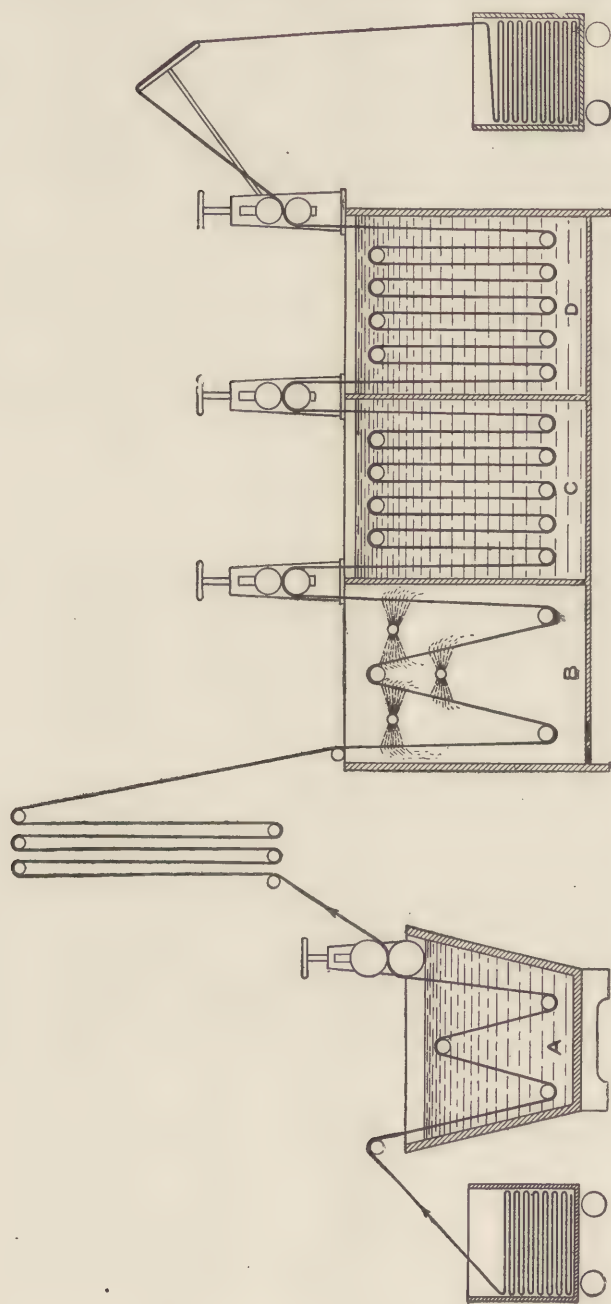


Fig. 73. Dyeing, Developing, and Washing Apparatus.

much cheaper to produce than Turkey-red and also of penetrating the material more thoroughly. Like Turkey-red, para red is not extremely fast to rubbing.

What has been said in regard to para red is in general true in regard to alpha naphthylamine red.

#### REDUCTION VAT COLORS.

**211. General Consideration.** Three dyestuffs of importance are included under this heading:

Indigo,  
Indanthrene,  
Flavanthrene.

These dyestuffs are all insoluble in water, but upon reduction in alkaline solutions are converted into soluble compounds, in which form they may be applied to cotton material. Upon exposure of the material to the air, oxidation takes place and the original insoluble compounds are formed, which become permanently fixed upon the fiber.

**212. Indigo.** This has already been considered in detail, under the head of Natural Coloring Matters (see No. 135) and need not be further discussed at this time.

**213. Indanthrene.** discovered in 1901, is made by fusing beta amino anthraquinone with caustic potash at a temperature of 250° C. It is insoluble in water, but when reduced by the action of hydrosulphite solution in a strongly alkaline bath, it passes into a soluble compound. In this respect, it resembles indigo and may be applied to cotton in a similar manner.

The dye bath should be made up as follows:

Indanthrene, Necessary amount to produce desired color.

Caustic soda, About 15%.

Sodium Hydrosulphite (10% solution) Five times the weight of Indanthrene.

Heat the bath to 140° F. and add the indanthrene mixed with 3 to 10 times its weight of water. Then add the caustic soda (previously dissolved) and finally the hydrosulphite solution. Stir constantly, keeping the temperature at 140° F. until complete solution of the indanthrene takes place.

The material is dyed in this bath for three-quarters of an hour at 140° F., but for light shades the temperature should be reduced and the period of dyeing increased.

The dyeing is followed by a short exposure to the air; then the material is washed, soured in dilute sulphuric acid, washed

again, and finally soaped. Indanthrene differs from indigo in that it has a decided affinity for cotton when in the reduced condition, and is not washed out even if it passes directly from the dyebath into the wash water, whereas indigo must be oxidized before it is washed.

Indanthrene gives excellent shades of blue, which possess remarkable fastness to light, washing, soaping, alkalies, and acids. When first placed upon the market, indanthrene was not at all fast to chlorine, but later a product known as Indanthrene C was introduced which possesses excellent fastness to chlorine.

**Flavanthrene** is produced by the oxidation of beta amino anthracene. It may be applied in the same manner as indanthrene and gives yellow shades which possess the same degree of fastness.

By combining indanthrene with flavanthrene in varying proportions, it is possible to get shades of green which possess greater fastness than any other class of greens.

Indanthrene and flavanthrene are applied in calico printing, and the dyeing of yarn for gingham, but their high cost has prevented their extensive use.

#### MISCELLANEOUS COLORS.

**214. Aniline Black.** In itself, aniline black is an insoluble black pigment of unknown composition produced by the oxidation of aniline. Probably a greater number of different methods have been tried for fixing this black pigment upon textile material than any other dyestuff or class of dyestuffs.

When *aniline is oxidized*, three consecutive products are formed: (1) Emeraldine, a greenish colored salt, insoluble in water; (2) Nigraniline, formed by the oxidation of emeraldine; (3) Aniline black proper, or ungreenable black as it is sometimes called, which is formed by the still further oxidation of nigraniline.

Aniline black is seldom applied to wool, but has been extensively used during the past forty years for the production of very fast blacks upon cotton cloth, hosiery, and to a much less extent upon cotton yarn and raw cotton. During recent years, the sulphur blacks have replaced aniline black to a considerable extent in dyeing, but not at all in calico printing.



In general, there are two methods of applying aniline black, the *Oxidation Method* and the *Single Bath Method*.

**215. Oxidation Method.** This consists in padding the material with a solution containing an aniline salt, usually the hydrochloride; some oxidizing agent, usually potassium or sodium chlorate; and certain metallic compounds, such as copper sulphide and vanadium salts which act as carriers of oxygen for the product of oxidized aniline black. Hundreds of recipes have been used and scarcely two dyers can be found using the same recipes and carrying out the process in the same manner. We will, therefore, only attempt to give general amounts in the preparation of the various baths.

For 100 parts of padding liquor:

Aniline Salt (Hydrochloride) 8 to 12 parts.

Sodium or Potassium Chlorate,  $3\frac{1}{2}$  to  $4\frac{1}{2}$  parts.

Copper Sulphide (30% paste) 1 part.

Thickener, enough to hold the copper sulphide in suspension.

Water, enough to make 100 parts.

In case vanadium compounds are used in place of copper sulphide, 40 to 65 mgs.,  $\frac{1}{2}$  to 1 grain per gallon of padding liquor is sufficient.

In another oxidation method, 5 parts of *potassium ferrocyanide* are added to the padding solution in place of the oxygen carrier. The material is padded, dried in the air, passed through a steam chamber if cloth, or as is usually the case with hosiery, aged in an oxidizing chamber in the presence of air.

The ageing is followed by a treatment with *potassium* or *sodium bichromate* solution which carries the oxidation still further.

**216. Single Bath Method.** A single bath method is sometimes used for dyeing raw cotton, cotton yarn, and cotton warps with aniline black.

The dye bath is prepared with:

Aniline Salt (Quantity depending upon depth of shade desired).

Potassium Bichromate,  $1\frac{1}{2}$  times the quantity of aniline salt.

Hydrochloric Acid, equal to or less than quantity of aniline salt.

Dissolve the aniline salt and potassium bichromate separately, and mix in perfectly cooled condition just before the dyeing. Add the acid in several portions during the dyeing which should start cold and continue

for two to three hours. The aniline will be better exhausted if the temperature is raised to 50° to 60° C. during the last half hour of the dyeing.

Aniline black is extremely fast to light, bleaching, and washing. The oxidation blacks are faster to rubbing than the single bath blacks, but the opposite is true in regard to fastness to acids.

## WATER AND ITS APPLICATION IN THE TEXTILE INDUSTRY.

### 217. Important Data in Regard to Water.

Composition By volume, 2 parts hydrogen 1 part oxygen.

By weight, 1 part hydrogen 8 parts oxygen.

Boiling Point 212° Fahrenheit Scale 100° Centigrade 70° Réamur.

Freezing Point 32° " " 0° " 0° "

Maximum Density of water at 39.2° F. or 4° C.

Water expands  $\frac{1}{10}$  of its volume upon freezing.

1 cu. ft. of water at 4° C. weighs 62.5 lbs.

Water at its maximum density is taken as the standard for specific gravity. See Part I. Page 39.

Raising the temperature above 4° C. or lowering it below 4° C. lowers the specific gravity of water. Thus,

Specific Gravity of water at	0° C.	.99987
" " " " " 4° C.	4° C.	1.00000
" " " " " 15° C.	15° C.	.99915
" " " " " 50° C.	50° C.	.98817
" " " " " 100° C.	100° C.	.95859

Latent heat of liquifaction of ice 79 heat units.

Latent heat of vaporization of water 537 heat units.

Boiling point of water increases under pressure and lowers under reduced pressure. Thus,

B. P. of water at normal atmospheric pressure	100° C.
" " " " 30 lbs. pressure approximately	120° C.
" " " " 90 " " "	160° C.
" " " " 120 " " "	170° C.

Boiling point of water is increased by the presence of soluble salts. Thus,

B. P. of distilled water	100.0° C.
" " 5% solution of common salt	101.5° "
" " 10% " " " "	103.0° "
" " 15% " " " "	104.6° "
" " 20% " " " "	106.3° "
" " 25% " " " "	107.9° "
" " 33% calcium chloride solution	128.0° "
" " 66% " " " "	156.0° "

**218. Impurities of Water.** If all water was pure, but little could be said in regard to it other than has been given in the above table. As a matter of fact, however, absolutely pure water may be looked upon as a curiosity. Distilled water is the nearest approach to pure water, and even when this is prepared very carefully under the most favorable conditions and with many precautions, it is never entirely free from traces of gaseous impurities. Assuming that absolutely pure water could be prepared, it would remain so but a few seconds when exposed to the air.

Normal water is therefore a water of impurities, and it is these impurities that will engage our attention in its study.

**Two Classes of Impurities.** The impurities present in water may be divided into two entirely different classes.

- (1) Those of importance from a physiological or *sanitary* point of view.
- (2) Those of importance from a technical or *industrial* point of view.

It is the latter class that will naturally engage our attention at this time.

**219. Classification of Waters.** We have already said that in the study of water it is the impurities contained therein that engage our attention. The nature of these impurities depends upon the substances with which the water has come in contact previous to the time of use or examination, and it is therefore advisable, especially for technical purposes, to classify various waters according to their sources.

Adopting this method we have

- (1) Distilled Water.
- (2) Rain Water.
- (3) Surface Water.
- (4) Subsoil or Ground Water.
- (5) Deep Well or Artesian Well Water.
- (6) Sea Water.
- (7) Mineral Water.

**220. Distilled Water.** On account of its freedom from mineral matter and other impurities, distilled water would obviously be the best form of water to use for textile and other industrial purposes, but the expense of its production is so great as to make its use impossible for anything but special purposes. In

chemical laboratories, however, it is indispensable for analytical and many experimental purposes, and consequently small stills producing anywhere from one to five gallons per hour are usually installed.

These stills may be heated by direct gas flame or what is better, by a steam coil inserted within the still, or by a steam jacket. Fig. 74 represents a cross section of such a still. The water in the still A is constantly kept at the level of the water in the condenser B by means of the cross connection C. Steam is introduced into the jacket J through the valve D and escapes through valve E, and by properly regulating these valves, the water in A may be boiled steadily for hours. The vapor passes over through the neck G, condenses in the worm B, which is surrounded by cold water, and

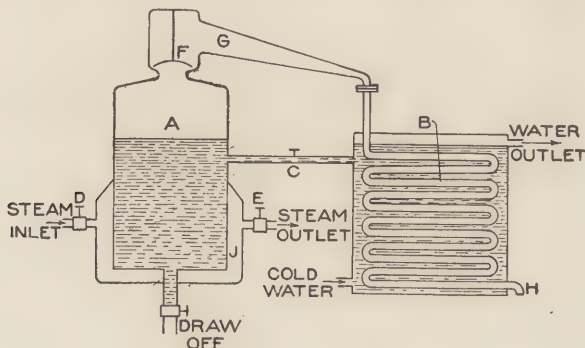


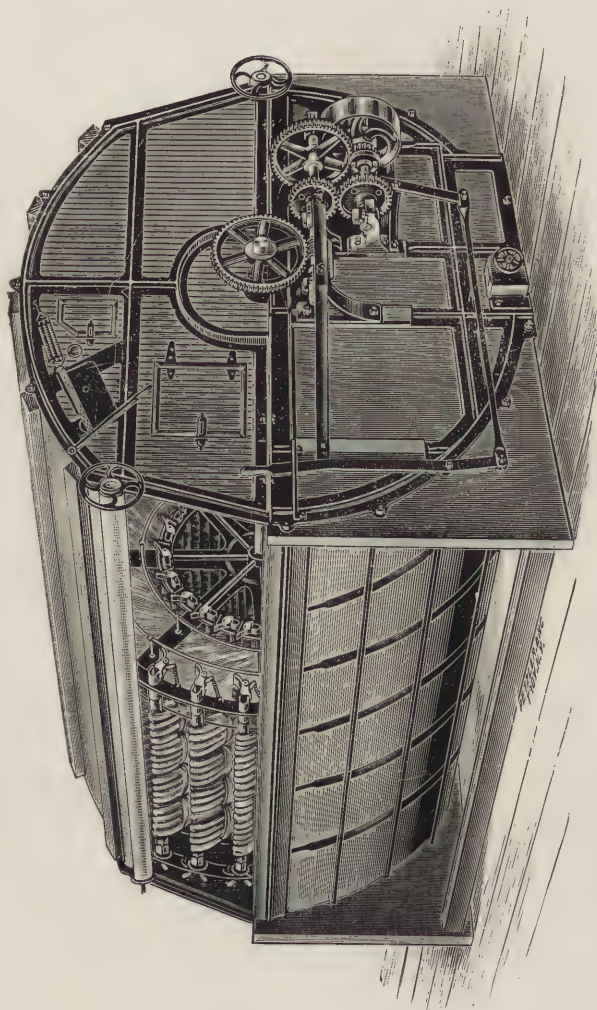
Fig. 74. Steam Heated Still.

finally issues at H as distilled. A baffle plate F may be located in the head of the still to prevent any water from being carried over mechanically in case the water in A should boil too violently.

In works where only a limited amount of pure water is required, it is sometimes the practice to condense direct steam from the boilers, or indirect steam that has already been used for heating purposes or otherwise. In this way a comparatively pure water is obtained, but its purity cannot always be depended upon, as oil, which is volatile with steam, is likely to get into it in various ways, and iron rust from steam pipes occasionally causes trouble.

**221. Rain Water.** Rain water may be considered a naturally distilled water. Evaporation is constantly going on at the





SKEIN AND SLUBBING MACHINE, CAPACITY FROM 250 TO 700 POUNDS PER BATCH  
Klander-Weldon Dyeing Machine Co.



surface of all bodies of water exposed to the atmosphere, and the water vapor thus formed, being lighter than the air, rises. The amount of evaporation varies, being but little upon a cold damp day but very great upon a warm and dry day. As the warm air, partially saturated with moisture, rises, it eventually becomes cooled to a point where a large proportion of the moisture it holds condenses out as clouds, which, being carried about by the various currents of air, constantly increase in density until they become so heavy that the water falls to the earth as rain.

Rain water, however, is never absolutely pure, for it always contains a certain amount of foreign matter, usually of a volatile character.

The degree of purity of rain water depends chiefly upon two conditions, *i. e.*: the locality and the period of the storm during which the rain fell. In a large city where many industrial establishments, such as gas works, bleacheries, chemical works, etc., are located, large quantities of gaseous impurities, such as ammonia, various oxides of nitrogen and chlorine, escape into the air, and in addition to these, sulphur compounds from the burning of enormous quantities of soft coal.

During the first few hours of a rain storm, these impurities, which in a dry season may have been collecting for several weeks, are readily absorbed by the rain, and the rain water falling at this time is likely to be more or less contaminated by impurities. After the rain has fallen for some time, these impurities are well extracted from the atmosphere, particularly in country districts, and rain water then becomes almost as pure as distilled water.

Rain water as actually collected, however, always contains additional impurities, owing to dust, dirt, etc., which collect upon roofs or other surfaces from which it is drained. In many works where only very hard water is obtainable, the collection of rain water may be made more of an item than is generally realized.

**222. Surface Water.** Under this head is included all surface bodies of fresh water, such as brooks, rivers, ponds and lakes. Sea water is a surface water, but being so rich in inorganic matter is classified separately.

When rain water strikes the earth a considerable portion is immediately absorbed, especially if the soil is of a dry and porous

character. It percolates through the soil to various depths and contributes to the fourth and fifth classes of water known as subsoil and deep well waters. After it has rained some time, the soil becomes more or less saturated, or perhaps the soil is already wet as is the case in a swampy region, and then that portion which is in excess of the amount absorbed, flows in the direction of the incline of the earth and soon contributes to brooks, rivers, lakes, and constitutes one of the two sources of surface water.

The second source of surface water is from springs consisting of subsoil water, which having passed through the earth has had an opportunity to dissolve various forms of mineral matter. As a rule, water from the second source contains more matter in solution than water from the first.

It can readily be seen, from its origin, that surface water will vary greatly in the nature and amount of impurities that it contains, these depending chiefly upon the locality and the conditions through which it has passed previous to the time of its examination. If surface water comes originally from a locality consisting of a hard and non-porous soil, and then passes over a river-bed composed of insoluble rocks, it will contain but few impurities and be nearly as pure as rain water. On the other hand, if it comes largely from spring water, and then passes over river-beds composed of limestone, dolomite, and gypsum, and finally through several cities or towns, it may contain a great variety of impurities, both organic and inorganic, and be unfit for either industrial or drinking purposes until purified.

**223. Subsoil Water.** This includes for the most part spring and shallow well water. The rain absorbed by the earth percolates through the soil to various depths until it reaches a strata of rock or soil, which is partially or wholly impervious to water. If this strata of impervious material slopes in either direction, the water will flow in the direction of the incline. A shaft sunk into the ground until it penetrates such an impervious layer, constitutes a shallow well. Oftentimes such an impervious strata of rock outcrops at the surface of the earth, usually upon the side of a hill, and constitutes a spring. The impurities contained in such a water depend almost entirely upon local conditions, that is, the nature of the soil through which it has passed and any artificial



sources of contamination that it may have met. The former impurities are of great importance from a technical standpoint, whereas the latter are of the utmost importance from a sanitary point of view.

**224. Deep Well or Artesian Well Water.** In some localities the formation of the crust of the earth is such that fissures or crevices extend into the earth to great depths. Their upper terminations may be in direct communication with lakes or rivers, but more often with subsoil water. The water from these sources has, during the course of time, completely filled all of the subterranean

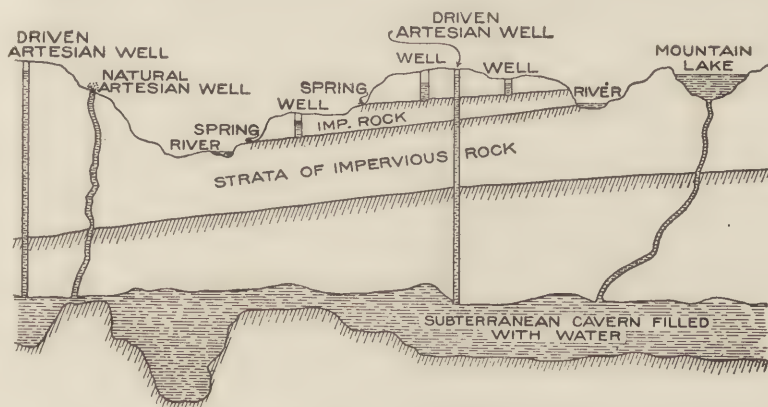


Fig. 75. Diagram Showing Sources of Water.

cavities with which the lower terminations of such fissures connect. Here it collects and, undoubtedly in many instances, forms large subterranean bodies of water, which are found located at a depth of many hundred feet below the surface of the earth. An artificial shaft sunk into the earth until it reaches such a subterranean body of water constitutes an artesian well. In some cases there is enough pressure behind the water to bring it to the surface without pumping.

Artesian well waters vary greatly in composition. Some are comparatively pure, while others are so rich in inorganic matter as to be classed as mineral waters.

**225. Sea Water.** Sea water contains between three and four per cent of soluble mineral matter which consists chiefly of sodium chloride and smaller quantities of the chlorides and sul-

phates of calcium and magnesium. Sea water cannot be used for ordinary purposes unless previously distilled.

**226. Mineral Waters.** In various localities, spring waters are found which are heavily charged with soluble inorganic compounds which have been dissolved by the passage of the water through various deposits in the earth. The mineral matter present is in such large quantities as to usually render them as unfit for industrial purposes as is sea water.

#### IMPURITIES EXISTING IN WATER AND THEIR CHEMISTRY.

**227. Classification of the Impurities in Water.** Impurities existing in water naturally divide themselves into two classes; first, those *not in solution*, which we will designate as mechanical or suspended impurities; secondly, those *in solution*, designated as dissolved impurities. As a rule, river water contains the least amount of dissolved impurities and the largest amount of suspended matter and inorganic impurities, while the opposite is true of the subsoil and well water.

**228. Mechanical or Suspended Impurities.** These impurities are more noticeable in river water than in any other variety. The rapidly flowing stream has an opportunity to take along with it finely powdered particles of matter, both mineral and organic, which are insoluble in water. A river flowing rapidly through a locality where the soil is of a light and pulverized nature, especially during the spring months, will contain large quantities of mechanical impurities. On the other hand a river with a slow current which passes through lakes, where there is an opportunity for suspended matter to settle out, may contain but little of this form of impurities.

**229. Soluble Impurities.** Under this head are classed all impurities which, under the conditions through which a water has passed, have been taken into solution. The solvent action of water is so great that surface and subsoil water always contain a certain amount of soluble matter, both of inorganic and organic origin, the nature of which depends entirely upon the character of the rock or soil over or through which the water has passed, and also to a certain extent, upon artificial contamination.

Waters whose origin is in a district composed of such insolu-

ble rocks as granite or gneiss remain comparatively free from inorganic impurities and are termed *soft waters*. On the other hand, waters passing through or over formations of limestone, dolomite, magnesite, red sandstone or gypsum, dissolve varying quantities of inorganic compounds and are known as *hard waters*.

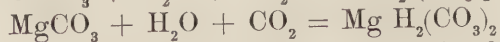
**230. Classification of Soluble Impurities.** For convenience the soluble impurities will be discussed according to the following classification:

- (a) 1. Calcium or magnesium impurities.
2. Iron impurities.
3. Alkaline impurities.
4. Acid impurities.
5. Organic impurities.
- (b) 6. Sea water and mineral water.

**231. Calcium or Magnesium Impurities.** Under this head are included all compounds of calcium and magnesium occurring in different forms of natural water.

From an industrial or technical point of view, these are of the utmost importance, as they occur more frequently than any of the other impurities, and if present in any quantity, may cause serious trouble in many industrial operations. They are most frequently present as the acid or bicarbonates and less often as sulphates and chlorides.

Calcium carbonate  $\text{CaCO}_3$  and magnesium carbonate  $\text{MgCO}_3$  are practically insoluble in water, but water which contains in solution carbon dioxide gradually dissolves these normal carbonates, converting them into acid or bicarbonates, according to the following equations:



Carbon dioxide ( $\text{CO}_2$ ) is often formed by the decomposition of organic matter and, as is frequently the case, rain water while passing through the earth comes in contact with the carbon dioxide thus formed. As the water passes through the earth the conditions of pressure and low temperature are favorable for the solution of the carbon dioxide and it is readily dissolved. Later in its course, this water, which is nothing more nor less than a solution of carbonic acid, may pass over limestone  $\text{CaCO}_3$ , magnesite  $\text{MgCO}_3$ , or dolomite  $\text{CaMg}(\text{CO}_3)_2$ , and a certain amount



of the calcium or magnesium become dissolved in the form of their bicarbonates.

Calcium and magnesium sulphates and chlorides are all more or less soluble in water, and if water comes in contact with any of these substances, they will be taken into solution. In some localities the mineral gypsum  $\text{CaSO}_4 + 2\text{H}_2\text{O}$  occurs in large quantities and is therefore not an uncommon impurity in water.

#### HARDNESS OF WATER.

**232. General Consideration.** In order to understand the exact nature of a hard water, one must be familiar with the composition of soaps, and their chemical nature. Soaps are the metallic salts of certain of the so-called fatty acids, the common soaps being the potassium and sodium salts of such acids as *stearic*, *palmitic*, *margaric*, etc. These potassium and sodium soaps or salts are for the most part readily soluble in water. There are other metallic salts such as those of calcium, magnesium, iron, lead, etc., with these same acids, and these are from a chemical point of view as truly soaps as the potassium and sodium compounds, but they are for the most part extremely insoluble in water.

The soaps in general use are those first mentioned, that is, the potassium and sodium soaps which are soluble in water. If these soaps are added to water free from mineral matter and acid, they readily dissolve and it takes but little to form a lather. Such a water is said to be *soft* and is particularly desirable in most industrial operations.

If, on the other hand, a water contains soluble salts of *calcium*, *magnesium*, *iron*, or in fact of any metal which forms an insoluble soap, and we add to such water one of the common potassium or sodium soaps, double decomposition takes place with the formation of an insoluble soap which is precipitated, and the formation of a potassium or sodium salt of the inorganic acid liberated. In this case no lather will be formed and the soap will have no action until all of the calcium, magnesium, iron, etc., has been precipitated as an insoluble soap. Such a water is said to be *hard* and is very objectionable in most industrial operations as it wastes large quantities of soap,



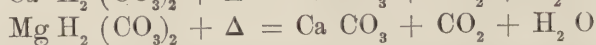
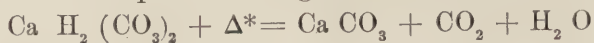
and the insoluble soaps formed are very disastrous in many cases.

In general it may therefore be said that a hard water is one containing in solution any metal capable of forming an insoluble soap.

**233. Temporary and Permanent Hardness.** Hardness of water may exist either as temporary or permanent hardness, or both combined.

#### TEMPORARY HARDNESS.

From previous definition it will be understood that a water containing the soluble acid or bicarbonates of calcium, magnesium, and iron, are hard. By boiling such a water, however, these bicarbonates decompose according to the following equations:



into the normal carbonates of calcium, magnesium and iron, which are insoluble in water. These metals would therefore be precipitated out, and being no longer in solution, they would not affect soap. The water is therefore rendered soft. This form of hardness is known as temporary hardness, and any water which loses its hardness upon boiling is said to be temporarily hard.

#### PERMANENT HARDNESS.

For the reasons previously mentioned, a water containing the chlorides of calcium or magnesium, or the sulphates of calcium and magnesium, or, in fact, any soluble sulphate, chloride or nitrate of a metal forming an insoluble soap, is hard. If such a water should be boiled under ordinary conditions, these salts would still remain unchanged, and the evaporation of the water would consequently, by concentration, increase the degree of hardness. Such a water is said to be permanently hard.

#### SCALES OF HARDNESS.

It is customary to express the hardness of water in degrees, two scales being extensively used for this purpose. First, Clark's scale, in which one degree of hardness corresponds to one grain of calcium carbonate, or its molecular equivalent of some other compound forming a hard water, per gallon of water. In other words

\*Note.  $\Delta$  is the symbol commonly used as representative of heat.

one part in seventy thousand. Secondly, Frankland's scale, in which one degree of hardness corresponds to one gram of calcium carbonate, or its molecular equivalent in some other compound, per one hundred thousand grams of water. In other words one part in every one hundred thousand.

Frankland's scale may be easily converted into Clark's by multiplying the number of degrees in the former scale by  $\frac{7}{10}$ , or *vice versa*, by multiplying Clark's scale by  $\frac{10}{7}$ .

**234. Iron Impurities.** Iron impurities include all compounds of iron which may occur in natural water. Similar compounds of manganese, which occur less frequently than iron, are often included under this same head. They occur principally in the neighborhood of coal mines, iron mines, and in localities where minerals containing iron abound. Iron occurs so abundantly and is so widely distributed in nature that water containing this metal may be found in almost any locality. It is usually present as the bicarbonate, having been dissolved by an excess of carbon dioxide.

As a rule the bicarbonate of iron decomposes quite readily into the normal carbonate. Simple exposure to the air and sunlight is often sufficient to purify the water by causing this precipitation to take place.

The *iron rust or oxide* which frequently collects in iron water pipes should not be confused with iron that is present in solution. Its presence is due wholly to local conditions which may easily be corrected, and is not detrimental to the purity of the water in its original form. Iron may also occur as the sulphate. Manganese acts similar to iron, but is not as frequently found in water.

**235. Alkaline and Saline Impurities.** In certain localities deep well water may contain an appreciable amount of sodium carbonate. This is particularly true in coal regions. Water that has received waste from a wool scouring plant, especially if it be a small river, may contain sufficient potassium salts to render the water slightly alkaline. In some localities, particularly in certain parts of New York state, deep well water is charged with comparatively large amounts of saline or salty impurities. Occa-

sionally there is enough present to render the water similar in composition to sea water.

**236. Acid Impurities.** Water that has drained through marshy or boggy districts may dissolve small amounts of organic acids, sometimes termed peaty acids. They easily attack iron and in some cases may be present in sufficient quantity to cause trouble.

When water is contaminated with ferrous sulphate, this compound may decompose upon exposure to the air and sunlight, forming ferric oxide with the liberation of free sulphuric acid.

*Hydrogen sulphide*, present in the so-called sulphur waters, may also be included as an acid impurity. It generally arises from the decomposition of calcium sulphate.

**237. Organic Impurities.** From a technical point of view organic impurities, unless present in large amounts, are not usually serious. In a drinking water, however, they are of the utmost importance. Organic impurities may be present in water that has passed through a marshy or swampy district, by the introduction of sewerage from cities and towns, by vegetable growth in the water, or by the introduction of waste liquors from various industrial establishments.

**238. Artificial Impurities.** Under this head may be classified all impurities which have been introduced into water by other than natural means. For this reason, they exist for the most part only in surface water. They vary greatly in quantity and character, depending wholly upon local conditions. Near the source of a stream there is little if any danger from such impurities, but great trouble is often experienced by manufacturers whose works are located near the mouth of a large stream that has passed through numerous towns and cities, receiving contributions from paper works, chemical works, bleacheries, dye houses and other industrial establishments.

In most cases strict laws exist in regard to the pollution of streams, but the expense and trouble in complying with these laws often leads a manufacturer to overlook the state laws, as well as the rights of other manufacturers located farther down the stream.



### EFFECTS OF IMPURE WATER IN THE DIFFERENT BRANCHES OF THE TEXTILE INDUSTRY.

**239. General Consideration.** The injurious effects of the impurities present in water are probably more numerous and varied in the textile industry than in any other. In bleaching, wool scouring, textile printing, and various dyeing processes, to say nothing of the action of impure water in boilers, the textile manufacturer is often confronted with serious problems. In order to overcome these difficulties, he may be obliged to change his water supply or install an extensive filtration or water softening plant.

For convenience in their consideration, we will study the effects of impurities in the same order that we have already discussed the impurities themselves, and finally consider the various methods that may be used for correcting and overcoming the various injurious actions of these impurities.

**240. Effect of Calcium and Magnesium Impurities.** More trouble arises from the presence of calcium and magnesium compounds in water than from any others. In wool scouring, or in fact in any operation where soap is to be used, the insoluble calcium and magnesium soaps are at first formed. Consequently the soap has no effect and no lather will be formed until a quantity of soap has been added sufficient to precipitate all the calcium and magnesium as insoluble soaps. The great waste of soap thus involved is not the only disadvantage, for the calcium and magnesium soaps are of a sticky nature and become attached to the fiber in such a manner that they cannot be removed by washing, and their presence often causes disastrous effects in subsequent dyeing and finishing operations.

With some dyestuffs these insoluble soaps act as *resists*, thus preventing the proper fixation of the color and resulting in light spots and streaks upon the dyed material. For other dyestuffs these insoluble soaps have a certain affinity thus causing a more perfect fixation of the color and consequently dark spots or streaks upon the dyed material. With certain basic colors the acid portion of the insoluble soap acts as a mordant, producing similar effects.

If a hard water is used for washing material after it has been soaped, an insoluble soap is often formed upon the fiber. In certain mordanting operations the presence of calcium and magnesium compounds tends to cause a premature precipitation of the mordant-



ing principle, which condition is not only wasteful, but is likely to result in a superficial fixation of the mordant and consequently dye shades which are not fast to rubbing.

The presence of calcium and magnesium impurities is also injurious in water used for the solution of dyestuffs, many colors; particularly those of the basic group, being precipitated as insoluble compounds.

In the dyeing of alizarine reds, a small amount of calcium in the dye bath may be an advantage, and in fact chalk is commonly added in small quantities, but even in this case, it is far better to use pure water and add the necessary amount of calcium compounds in such forms as are most beneficial during the dyeing process.

In *dyeing with the alizarine colors*, the presence of calcium and magnesium in the form of bicarbonates is very objectionable, as is the case with most of the mordant dyestuffs.

The absence of calcium and magnesium impurities is also of the utmost importance in waters used for boiler purposes, their presence resulting in formation of boiler scale. This, however, will be considered later in a special number.

**241. Action of Iron Impurities.** In their action towards soaps, compounds of iron are similar to those of calcium and magnesium, precipitating insoluble soaps. When the iron is present as the bicarbonate, it decomposes easily with the formation of the insoluble normal carbonate; which may become deposited upon the fiber and interfere seriously in bleaching, scouring, and dyeing operations.

Even the smallest quantities of iron are very injurious in the production of alizarine or Turkey-red, for with alizarine, iron acts as a mordant producing purplish black instead of red color lakes. Minute quantities of this darker color lake materially dulls the resulting red.

*In bleaching processes*, particularly of cotton, iron compounds, if present in the final wash water, are liable to become deposited upon the cloth. If locally deposited, brownish spots will be formed, but if the deposit is general it will slightly yellow the material and detract from its final whiteness.

Iron present mechanically in the water as an oxide must be guarded against as well as iron compounds in solution. In bleach-

ing with sodium peroxide, even small quantities of iron in the water detract decidedly from the resulting white. Manganese impurities, if present, produce effects similar to those produced by iron.

**242. Alkaline Impurities.** In wool scouring, or in fact in any operation where sodium carbonate or any other alkali is a normal constituent of the bath, alkaline impurities may be overlooked. In mordanting operations their presence may cause a premature decomposition of the mordanting principle, but in the application of acid dyestuffs they cause no particular trouble other than the necessity of adding a larger amount of acid in the dye bath.

**243. Effect of Acid Impurities.** Acid water is unsuitable for scouring purposes since it wastes the soap, not by the formation of an insoluble soap, but by the liberation of the insoluble fatty acid of which the soap is a salt. In certain dyeing operations acid impurities may prove injurious.

**244. Action of Organic Impurities.** Organic impurities, unless present in large quantities, are in most cases without action. There are times, however, when organic impurities may be present in sufficient quantity to discolor the water. If present in the final wash water they may detract from the whiteness of bleached cloth and from the production of delicate tints.

**245. Action of Mechanical Impurities.** Mechanical impurities may be present in sufficient quantity to cause trouble in various textile operations, particularly in bleaching and scouring. A water containing mechanical impurities, as, for instance, mud, is bound to detract from the whiteness of bleached cloth if used in the final washing.

**246. Action of Impure Waters in Boilers (Boiler Scale).** At this time it is unnecessary to enter into a discussion of the various types of boilers in use, suffice to say that in all boilers a certain condition exists, namely, plates or tubes of iron of varying thickness heated by direct flame upon one side and in contact with water upon the other.

If the water used in a boiler contains soluble bicarbonates of *calcium*, *magnesium*, and *iron*, these will be precipitated as the normal carbonates, which, if no other compound is present, will

usually deposit in a finely divided condition upon the bottom and exposed surfaces of the boiler in the form of a mud, which may be blown out of the boiler from time to time and thus cause no serious trouble.

If a boiler water contains, in addition to the bicarbonates, calcium and magnesium sulphates or chlorides, an entirely different condition exists, for as evaporation takes place, the water eventually becomes saturated with these compounds, and as they crystallize out, form a hard crystalline deposit which tends to cement the loose particles of the normal carbonate together thus forming a hard and difficultly soluble crust upon the bottom and exposed surfaces of the boiler. This crust is commonly known as *boiler scale*.

The presence of this boiler scale increases with great rapidity the amount of coal necessary to evaporate a given weight of water, for it is a poor conductor of heat and it is with difficulty that the heat is conveyed through it from the fire to the water. Furthermore, it lessens the capacity of the boiler by diminishing its cubical contents.

The most serious result, however, comes when this deposit increases to such a thickness that the heat cannot be conducted through it sufficiently fast to prevent the iron plates or tubes from becoming overheated. This condition results in the warping and eventually cracking of the plates or tubes, thus allowing water to flow into the fire-box and suddenly generating an enormous quantity of steam, which has resulted in some of the most disastrous of boiler explosions. The necessity of pure water for boiler purposes is therefore obvious.

**247. Prevention of Boiler Scale.** Boiler scale may be prevented by one of three methods:

*First*, by adding to the boiler some substances or combination of substances that will cause the mineral matter present in the water to deposit in a loosely divided condition that may be easily blown out of the boiler from time to time.

*Second*, by heating the water in an auxiliary boiler before it enters the boiler proper, thus depositing the scale in the first boiler, which is so constructed that it may be removed from time to time without serious inconvenience.



*Third*, by chemically treating the water with some chemical compound or mixture of chemical compound which will precipitate the objectionable mineral matter, and then removing this

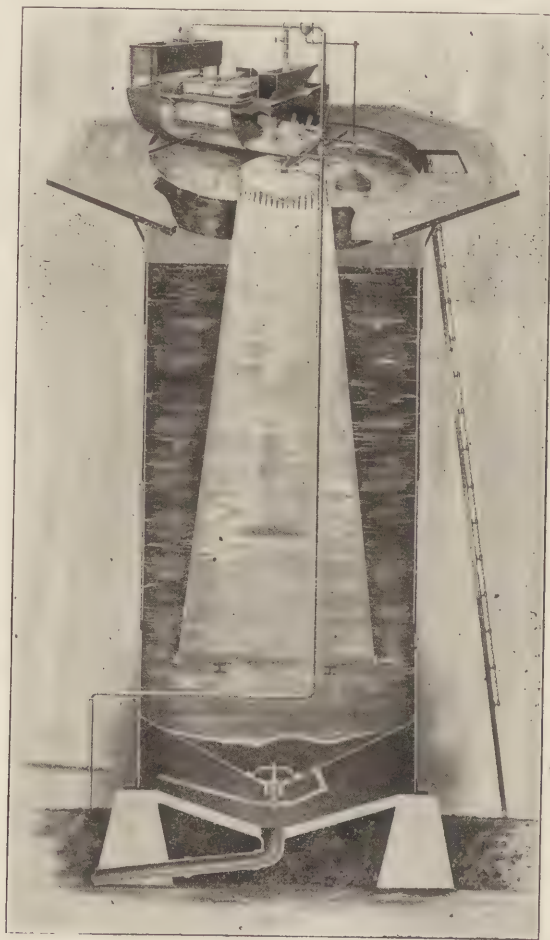


Fig. 76. Kennicott Water Softener.

from the water by filtration or decantation before the water enters the boiler.

The first method is used with varying success. It may work well with a temporarily hard water, but cannot be depended upon unless based upon a chemical analysis of the water and prepared with chemical exactness. Substances which are purely mechanical



in action are often added to boilers to prevent boiler scale. Among these may be mentioned various forms of *oil, bran, sawdust, sugar, molasses*, and innumerable other substances.

In the case of oils, they have a tendency to form a thin film about each particle of precipitated matter, thus preventing the particles from becoming cemented together. In the case of bran, sawdust and like substances, the particles of these, becoming mixed with the depositing particles of mineral matter, form a mud or sludge rather than a scale.

Other of the so-called boiler compounds are chemical in their action, various alkaline chromates and barium compounds being used, which tend to precipitate the objectionable substances in the water in a finely divided condition, as these substances have little tendency to crust or cake together. These boiler compounds, however, cannot be depended upon unless their use is based upon the analysis of the water and then prepared quantitatively with chemical exactness.

The second method of preventing boiler scale is not practical unless an enormous quantity of waste heat is available. It is therefore seldom used.

The third method, that is, purification of the water before it enters the boiler, is by far the best and will be discussed later under the headings Water Softening, and Filtration.

#### PURIFICATION OF WATER

**248. General Consideration.** From what has already been stated in the preceding pages, it is obvious that for many purposes, particularly in connection with the textile industry, it is essential that an impure water be purified before being used. If such a water is extremely hard, chemical means must be resorted to and the process usually comes under the general head of water softening.

If only mechanical impurities and organic matter are present in the water, various forms of filtration may be sufficient, but it must be remembered that ordinarily filtration does not remove the hardness of a water. We will therefore consider the purification of water under two heads, *i. e.*, Water Softening, and Filtration.

**249. Water Softening.** The various processes of water

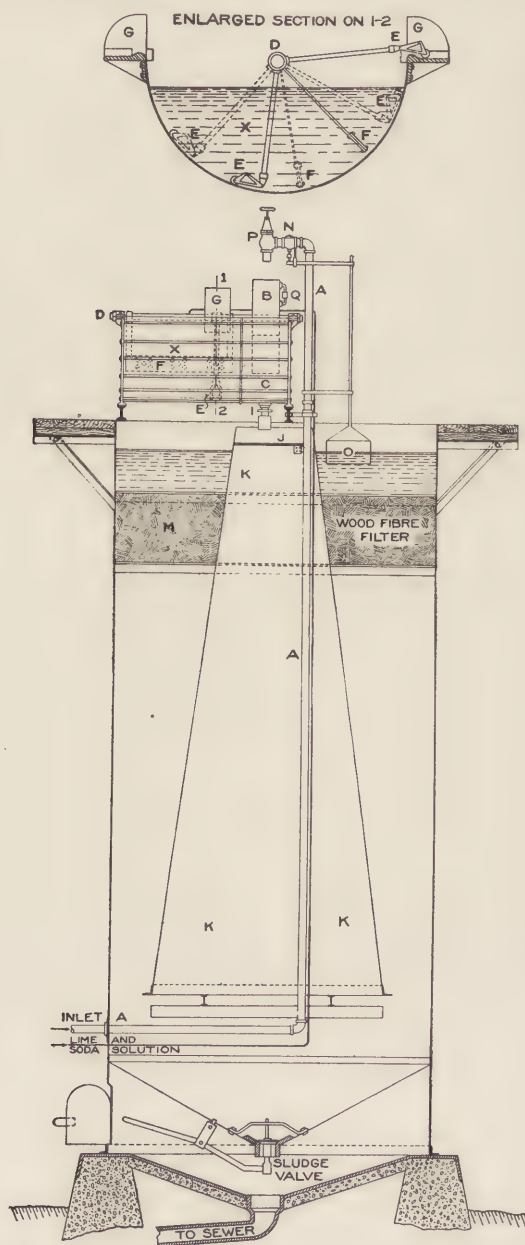
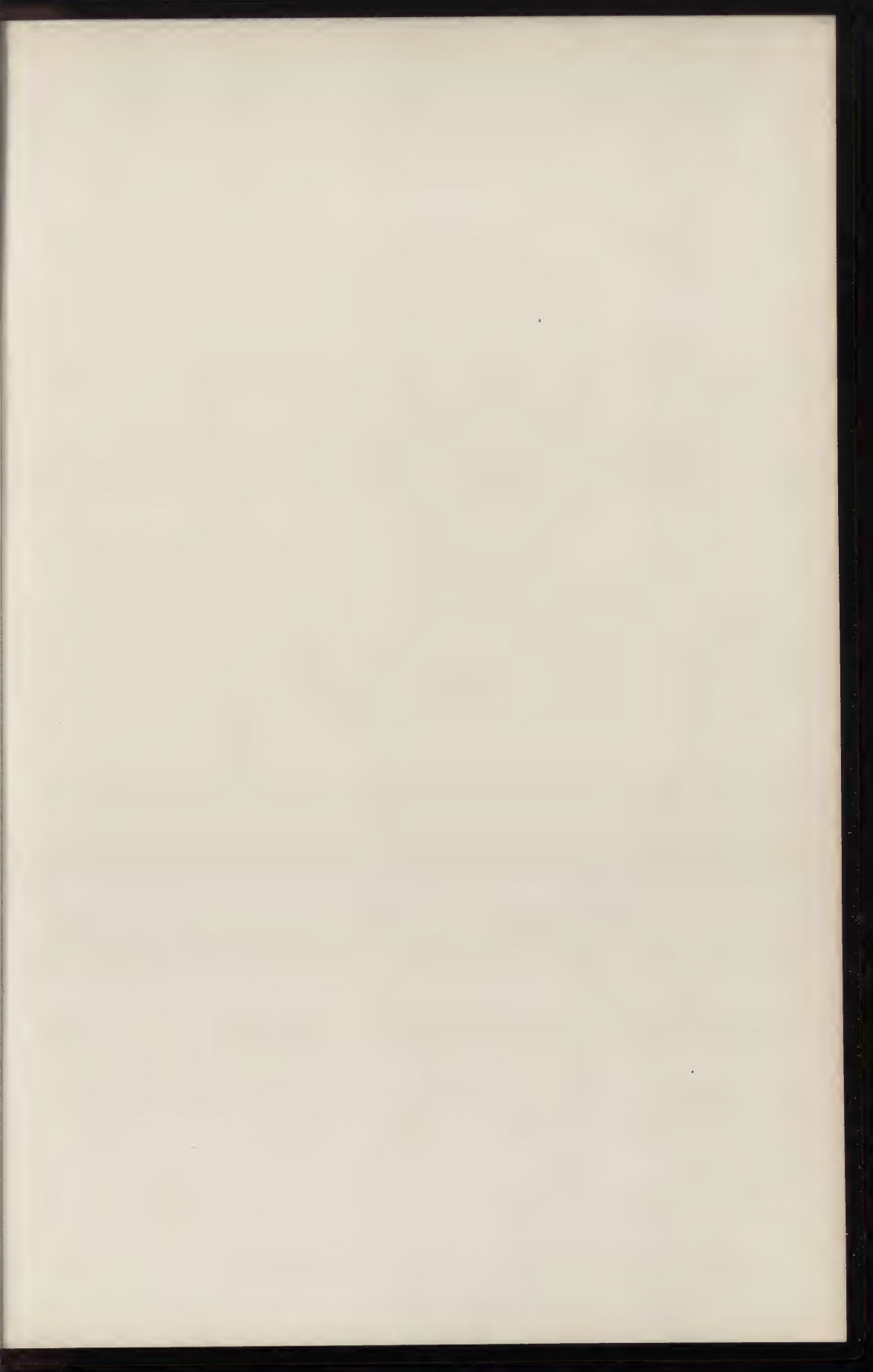
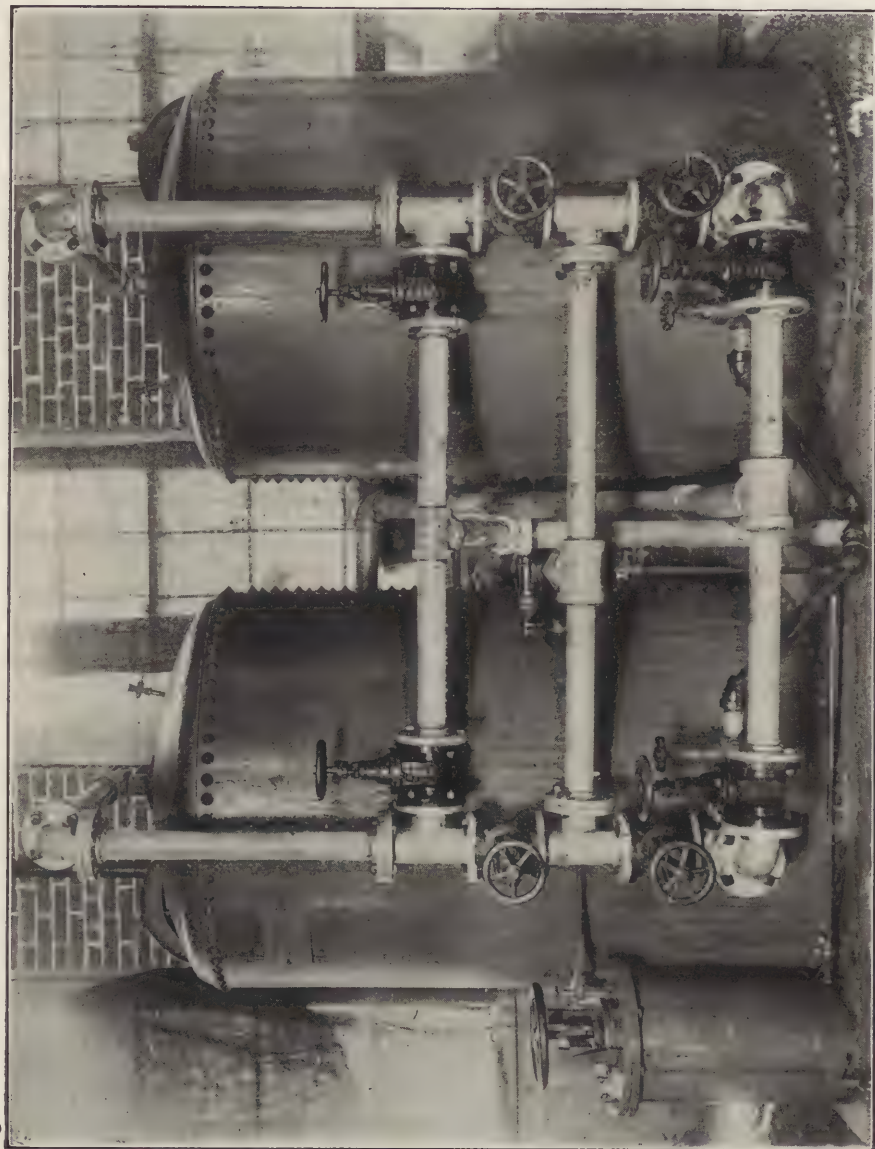


Fig. 77. Front Elevation of Kennicott Water Softener.



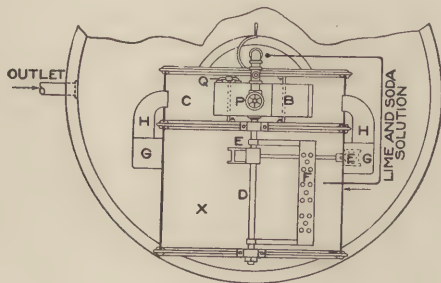


**FILTER PLANT INSTALLED AT NICETOWN DYE WORKS, PHILADELPHIA**

The Philadelphia Water Purification Co.



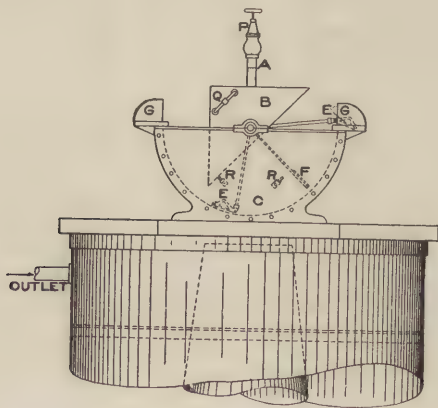
softening consist essentially of two steps; first, the chemical precipitation of the objectionable mineral matter in an insoluble state, and secondly, the subsequent removal of this precipitate by mechanical means. The chemistry of the precipitation is com-



Plan of Fig. 77.

paratively simple, but the various forms of apparatus for removing this precipitate from the water are more or less complicated.

The commonest re-agents used as precipitants are *sodium carbonate* and *calcium hydroxide*. These are added to the water



Side Elevation of Top of Fig. 77.

in just the right proportion to react with the mineral matter present according to the following equations:

*First*, assuming that the water is only temporarily hard:



By this method it will be seen that if lime water is added

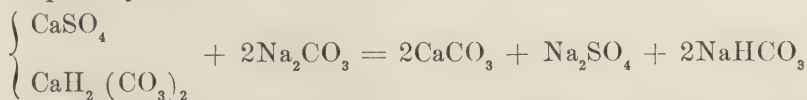
in just the right amount, the water will be rendered soft without the permanent introduction of any chemical compound.

*Second*, assuming that the water is permanently hard:



In this case sodium sulphate will remain dissolved in the water, but this is no serious objection as its presence causes no great trouble in boilers.

*Third*, assuming that the water is both permanently and temporarily hard:



With *magnesium compounds* the equations would be similar to those above substituting magnesium for calcium. Iron, if present, would act in a similar manner.

The precipitated carbonates may be removed by filtration, but more commonly by decantation in some form of a softening tower.

Figures 76 and 77 illustrate the Kennicott apparatus made by the Kennicott Water Softener Co., of Chicago. The water mixes with the softening reagents as it enters the apparatus; which is so constructed that the insoluble carbonates will settle out completely before the water leaves it, providing that the circulation is not too rapid.

The water for treatment enters the apparatus from the pumps or other source of supply through A (Fig. 77), and after passing through the automatic regulating valve N, which is controlled by float O, it enters the oscillating receptacle B, from which it is discharged into compartment C. A rocking motion through an arc of about 90° is given to the shaft D by the movement of the oscillating vessel B. Firmly attached to the shaft D are arms which carry cups E. These cups moving in unison with the oscillating vessel B follow the curved sides of the solution tank X, which contains the lime and soda, and are so designed as to scoop up and discharge the requisite amount of these chemicals. The milk of lime and soda solution is kept thoroughly agitated by means of the agitator F. The cups discharge into the hoods G and the mixture of lime and soda is conducted through troughs H into the water as it is discharged from the oscillating vessel B.

The valve I is a simple slide valve, set so that the water does not all flow into the settling tank as quickly as it is dumped from the receptacle B, but the space C will always contain at least a small amount of water, so that, as previously stated, there is practically a steady stream of water mixed with chemicals going into the settling tank. An exceptionally thorough mixture of the chemicals and water is obtained in the apparatus owing to the peculiar bonnet or spout placed over the discharge bar of the tilting receptacle, which, as it dumps, discharges a powerful stream of water into the space C, thus thoroughly mixing the water and

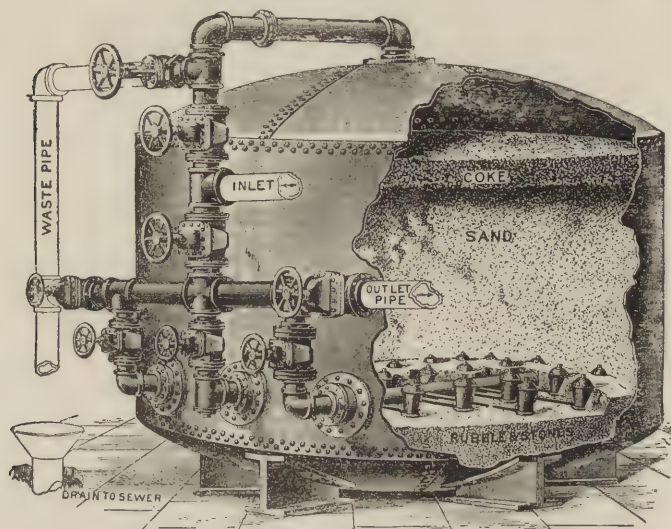


Fig. 78. Water Filter.

chemicals. The water, after passing valve I, falls upon the distributing plate J, then slowly passing through the conical down-take K, turns and rises, finally passing through the wood fiber filter M and emerges from the softener at the outlet soft and ready for use.

**250. Filtration of Water.** Two different methods of filtration are in practical use, *i. e.*, the so-called European and American systems.

In the *European system*, a large filter bed is prepared five or six feet in thickness and constructed of coarse gravel at the bottom, gradually growing finer as it approaches the top, where there are



several inches of sand. The water to be filtered is allowed to flow over this filter bed and gradually percolates through it. After the filter bed has been in use for some time, a thin deposit of silt and organic matter deposits upon the upper surface and gradually coats each individual grain of sand in the upper layer. This upper layer filters out all mechanical impurities present in the water and reduces the number of bacteria present in the water to a marked degree.

With the European system a filter bed of large area is necessary, and it is not very efficient until it has been in operation for

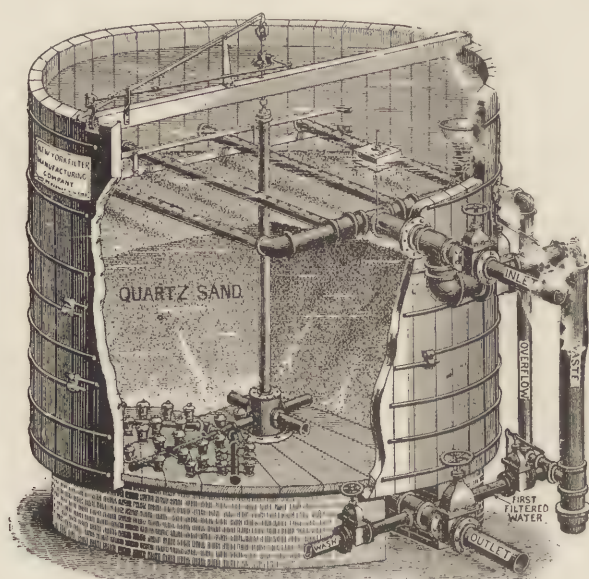


Fig. 79. Water Filter.

several weeks, but with proper care it can then be used for a long time. This method of filtration is extensively used for the purification of drinking water in large cities, but less frequently in industrial establishments.

The *American system* aims to produce, by artificial means, a condition similar to the European system. Cylindrical filters are constructed and filled with broken quartz, coke, and sand, as illustrated in Figs. 78 and 79.

Before the water enters this filter a small amount of alumi-



nium sulphate is added, which reacts with impurities present in the water and forms minute particles of aluminium hydroxide, which are of a gelatinous nature. This gelatinous precipitate collects upon the individual particles of sand in the upper layer of the filter bed, and when water is forced through the filter under pressure, and in some cases by gravity, it retains through its adhesive character the minutest particles of suspended matter and bacteria.

At the end of the day water is forced through the filter in the opposite direction in order to thoroughly scour it out. This system is not only used for drinking waters but is very extensively used in industrial plants.

**251. Correction of Water by Simple Additions.** In many operations the injurious action of the water may be corrected by simple chemical additions without resorting to filtration or the use of extensive softening plants. In many dyeing operations the addition of acetic acid converts the bicarbonates of calcium and magnesium into the acetates which are not objectionable.

An alkaline water may be neutralized by the addition of a small amount of acid, and an acid water may be corrected by the addition of a small amount of some alkali.

The injurious action of iron in alizarine dyeing is sometimes corrected by the addition of ammonium sulpho-cyanate.

The addition of sodium carbonate, sodium chromate and bichromate, and barium chloride in the right proportion to a hard water that is to be used for boiler purposes will often cause the precipitation of the injurious mineral matter in a finely divided non-incrusting condition, and if blown out of the boiler at regular intervals, the introduction of a softening plant may sometimes be avoided.

If a hard water is to be used for scouring purposes, sufficient sodium carbonate should be added to precipitate the calcium and magnesium before it enters the scouring bath.

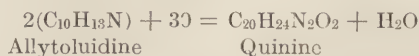
#### DISCOVERY OF ARTIFICIAL DYESTUFFS

The present year (1906) marks the fiftieth anniversary of the discovery of the first artificial dyestuff by William Henry Perkin. The celebration of no event has ever brought forth more general

interest among men of science and chemical industry and been more fittingly observed both in America and abroad, than this discovery. Perkin made his discovery when but a youth of eighteen, and no doubt the interest in this celebration is greatly enhanced by the fact that Perkin is still alive, actively engaged in chemical research, and is the central figure of the various exercises and festivities.

In presenting an account of Perkin's early investigations, we can do no better than quote, directly, his own words abstracted from a lecture on Hofmann, delivered by Dr. Perkin and published in the *Journal of the Chemical Society* of June, 1896.

"As a young chemist I was ambitious enough to wish to work on the subject of the artificial formation of natural organic compounds. Probably from reading some remarks on the importance of forming quinine, I began to think how it might be accomplished, and was led by the then popular additive and subtractive method to the idea that it might be formed from toluidine by first adding to its composition  $C_8H_4$ - by substituting allyl for hydrogen, thus forming allyltoluidine, and then removing two hydrogen atoms and adding two atoms of oxygen, thus



"The allyltoluidine having been prepared by the action of allyl iodide on toluidine, was converted into a salt and treated with potassium dichromate; no quinine was formed, but only a dirty reddish-brown precipitate. Unpromising though this result was, I was interested in the action, and thought it desirable to treat a more simple base in the same manner. Aniline was selected, and its sulphate was treated with potassium dichromate; in this instance a black precipitate was obtained, and, on examination, this precipitate was found to contain the colouring matter since so well known as Aniline Purple or Mauve, and by a number of other names. All these experiments were made during the Easter vacation of 1856 in my rough laboratory at home. Very soon after the discovery of this colouring matter I found that it had the properties of a dye, and that it resisted the action of light remarkably well.

"After the vacation, experiments were continued in the evening when I had returned from the Royal College of Chemistry, and combustions were made of the coloring matter. I showed it to my

friend Church, with whom I had been working, on his visiting my laboratory, and who, from his artistic tastes, had a great interest in colouring matters, and he thought it might be valuable, and encouraged me to continue to work upon it; but its evident costliness and the difficulties of preparing aniline on the large scale, made the probability of its proving of practical value appear very doubtful. Through a friend, I then got an introduction to Messrs. Pullar, of Perth, and sent them some specimens of dyed silk. On June 12th, 1856 I received the following reply:

“If your discovery does not make the goods too expensive, it is decidedly one of the most valuable that has come out for a very long time. This colour is one which has been very much wanted in all classes of goods, and could not be obtained fast on silks, and only at great expense on cotton yarns. I enclose you pattern of the best lilac we have on cotton—it is dyed only by one house in the United Kingdom, but even this is not quite fast, and does not stand the tests that yours does, and fades by exposure to air. On silk the colour has always been fugitive; it is done with cudbear or archil, and then blued to the shade.”

“This somewhat lengthy extract is quoted because it gives a glimpse at the state of the dyeing trade in reference to this shade of colour at that period.

“This first report was very satisfactory; the “if” with which it commenced was, however, a doubtful point.

“During the summer vacation, however, the preparation of the colouring matter on a very small technical scale was undertaken, my brother (the late T. D. Perkin) assisting me in the operations, and, after preparing a few ounces of the product, the results were thought sufficiently promising to make it desirable to patent the process for the preparation of this colouring matter. This was done on August 26, 1856. (Patent No. 1984.)

“A visit was then made to Messrs. Pullar’s and experiments on cotton dyeing were made, but as no suitable mordants were known for this colouring matter, only the pale shades of colour, produced by the natural affinity of the dye for the vegetable fibre, were obtained; these, however, were admired. Experiments on calico printing were also made at some print works, but fears were entertained that it would be too dear, and, although it proved to be one



of the most serviceable colours as regards fastness, yet the printers were not satisfied with it because it would not resist the action of chloride of lime like madder purple.

"Although the results were not so encouraging as could be wished, I was persuaded of the importance of the colouring matter, and the result was that, in October, I sought an interview with my old master, Hofmann, and told him of the discovery of this dye, showing him patterns dyed with it, at the same time saying that I was going to undertake its manufacture, and was sorry that I should have to leave the Royal College of Chemistry. At this he appeared much annoyed, and spoke in a very discouraging manner, making me feel that perhaps I might be taking a false step which might ruin my future prospects. I have sometimes thought that, appreciating the difficulties of producing such compounds as aniline and this colouring matter on a large scale, Hofmann perhaps anticipated that the undertaking would be a failure, and was sorry to think that I should be so foolish as to leave my scientific work for such an object, especially as I was then but a lad of eighteen years of age; and I must confess that one of my great fears on entering into technical work was that it might prevent my continuing research work, but I determined that, as far as possible, this should not be the case.

"Still, having faith in the results I had obtained, I left the College of Chemistry and continued my experiments, and found that not only aniline, but also toluidine, xyloidine, and cumidine gave a purple colouring matter when oxidized.

"The following is a copy of the principal part of the complete specification of the patent I took out at that time:

#### DYEING FABRICS

"The nature of my invention consists in producing a new colouring matter for dyeing with a lilac or purple colour stuffs or silk, cotton, wool, and other materials in the manner following:

"I take a cold solution of sulphate of aniline, or a cold solution of sulphate of toluidine, or a cold solution of sulphate of xyloidine, or a cold solution of sulphate of cumidine, or a mixture of any



of such solutions with any others or other of them, and as much of a cold solution of a soluble bichromate as contains base enough to convert the sulphuric acid in any of the above-mentioned solutions into a neutral sulphate. I then mix the solutions and allow them to stand for 10 to 12 hours, when the mixture will consist of a black powder and a solution of a neutral sulphate. I then throw this mixture upon a fine filter, and wash it with water till free from the neutral sulphate. I then dry the substance thus obtained at a temperature of 100° C., or 212° F., and digest it repeatedly with coal-tar naphtha, until it is free from a brown substance which is extracted by the naphtha. Any other substance than coal-tar naphtha may be used in which the brown substance is soluble and the colouring matter is not soluble. I then free the residue from the naphtha by evaporation, and digest it with methylated spirit, or any other liquid in which the colouring matter is soluble, which dissolves out the new colouring matter. I then separate the methylated spirit from the colouring matter by distillation, at a temperature of 100° C. or 212° F.”

As stated above, this coal-tar colouring matter, known as Mauve was patented the 26th of August, 1856, and after a number of obstacles and defects had been overcome, the actual manufacture of this dyestuff began at Greenford Green, near Harrow, England, in December of 1857. From this small beginning, the artificial dyestuff industry has grown so as to have become one of the most, if not the most extensive of the chemical industries, and to-day there are at least fifty concerns actively engaged in the manufacture of coal-tar coloring matters. Of this number more than half are located in Germany, and among these are some of enormous magnitude, as for instance, The Badische Anilin und Sodafabrik, Ludwigshafen am Rhein; The Farbenfabriken Company, of Elberfeld, Germany; Leopold Cassella and Co., Frankfort-am-Main; The Hoechst Farbwerke; and the Berlin Aniline Works.

The five concerns, just mentioned, probably manufacture 75% of all of the artificial dyestuffs made, and the following statistics in regard to the Hoechst Farbwerke, collected in 1904,\* will give an excellent idea as to the extent to which the industry has developed.

\* From "Year Book for Colorists and Dyers." Vol. VII, 1904.

## THE HOECHST FARBWERKE IN 1904

Workmen.....	5000
Overseers.....	200
Chemists.....	185
Technical Officials.....	60
The commercial department, excluding salesmen.....	340

The total ground covered by the works including dwellings for workmen is 341.28 acres.

Corporation buildings under cover, excluding dwellings, 59.82 acres.

Railway Track.....	26.09 miles
Locomotives.....	18
Steam Cranes.....	4
Wagons.....	1060
Steam boilers.....	118
With heating surface of.....	116,389 sq. ft.
Steam engines.....	210
Capacity.....	12,200 h. p.
Electric motors.....	130
Capacity.....	2800 h. p.
The works are lighted with 370 arc lights and 6000 incandescent lights.	
The daily consumption of coal is.....	662 tons
The daily water consumption is.....	145,49350 gallons
The daily gas consumption is.....	529,717 cu. ft.
The daily ice consumption is.....	750,000 lbs.

## OUTPUT

The total movement in and out by rail is 268,963 tons.

The total movement in and out by water is 319,670 tons.

The various beneficial organizations of the Farbwärke have grown so that now the statistics are as follows:

The Kaiser Wilhelm and Augusta funds	
amount to.....	1,688,000 marks
The Overseers' Pension Fund.....	332,000 marks
Pension fund of executive and clerical force	1,653,000 marks
The reserve of the department sick relief	
fund is now.....	142,000 marks
The savings bank deposits amount to.....	668,000 marks

The improvements contemplated have been finished during the past year and the dwellings for workmen and overseers number now 670, besides 50 residences for the official staff.

The pension and relief system of this concern is worthy of special notice, for all sick and injured workmen, as well as those who have reached a certain age, receive sufficient money to comfort-

ably provide for them. Extensive libraries, dormitories, restaurants, bath houses, and a savings bank are also provided by this progressive concern for its employes.

#### CHRONOLOGY OF IMPORTANT DISCOVERIES IN THE COAL-TAR DYESTUFF INDUSTRIES

The following chronology of some of the important discoveries in regard to the coal-tar industry will give some idea of its development.

- 1856 Perkin's Mauve. First artificial dyestuff prepared on a commercial scale.
- 1858 Hofmann's Aniline Red or Magenta. Discovered and manufactured the following year by Verguin.
- 1863 Aniline Black. Patented by Lightfoot.
- 1864 Bismark Brown. (First important azo dyestuff prepared.)
- 1864 Martius Yellow. (First important nitro dyestuff prepared.)
- 1868 Artificial Alizarine. Prepared by Grabe and Liebermann.
- 1874 Eosine, the first of the phthalic anhydride colors prepared.
- 1876 Discovery of the Griess reaction, which lead to the manufacture of Chrysoidine and the many azo dyestuffs which followed.
- 1877 Introduction of the process of sulphonating basic colors.
- 1880 Artificial preparation of indigo by Baeyer.
- 1884 Congo Red, first of the Direct Cotton Colors, prepared by Boettiger.
- 1890-1896 Introduction of the insoluble azo colors and the development of the sulphur colors and mordant acid colors.

#### NUMBER OF ARTIFICIAL DYESTUFFS

The latest edition (1902) of Schultz and Julius, "Tabellarische Uebersich der Kunstlichen Organischen Farbstoffen" (Tabular View of the Artificial Organic Dyestuffs), which is the standard dictionary of the coal-tar colors, describes 681 dyestuffs of different chemical composition.

NOTE: The development of the artificial dyestuff industry is well illustrated by the following table which gives the period of introduction of these 681 dyestuffs.

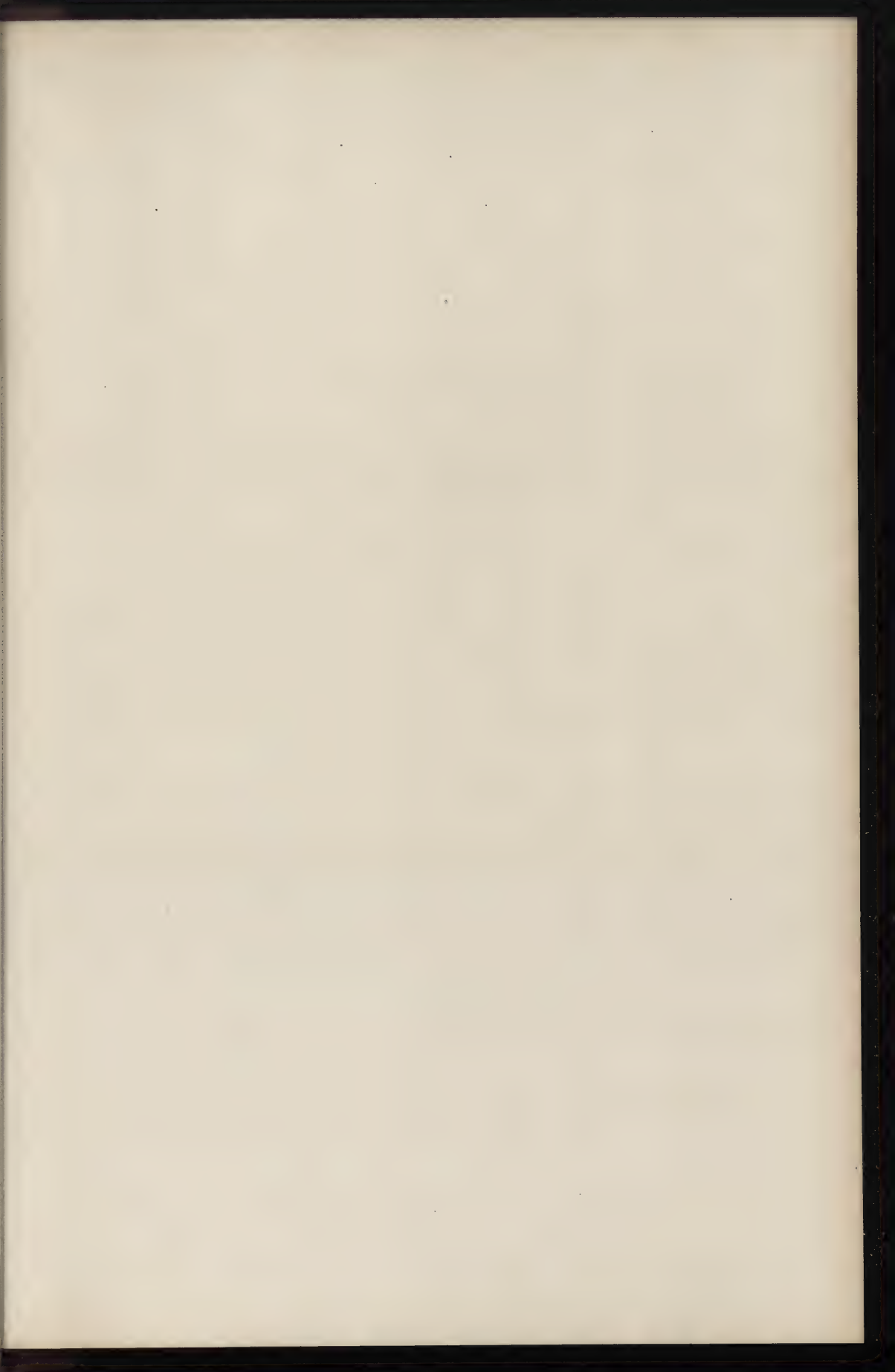
16	Previous to 1860	
39	Between	1860-1870
125	"	1870-1880
261	"	1880-1890
240	"	1890-1902

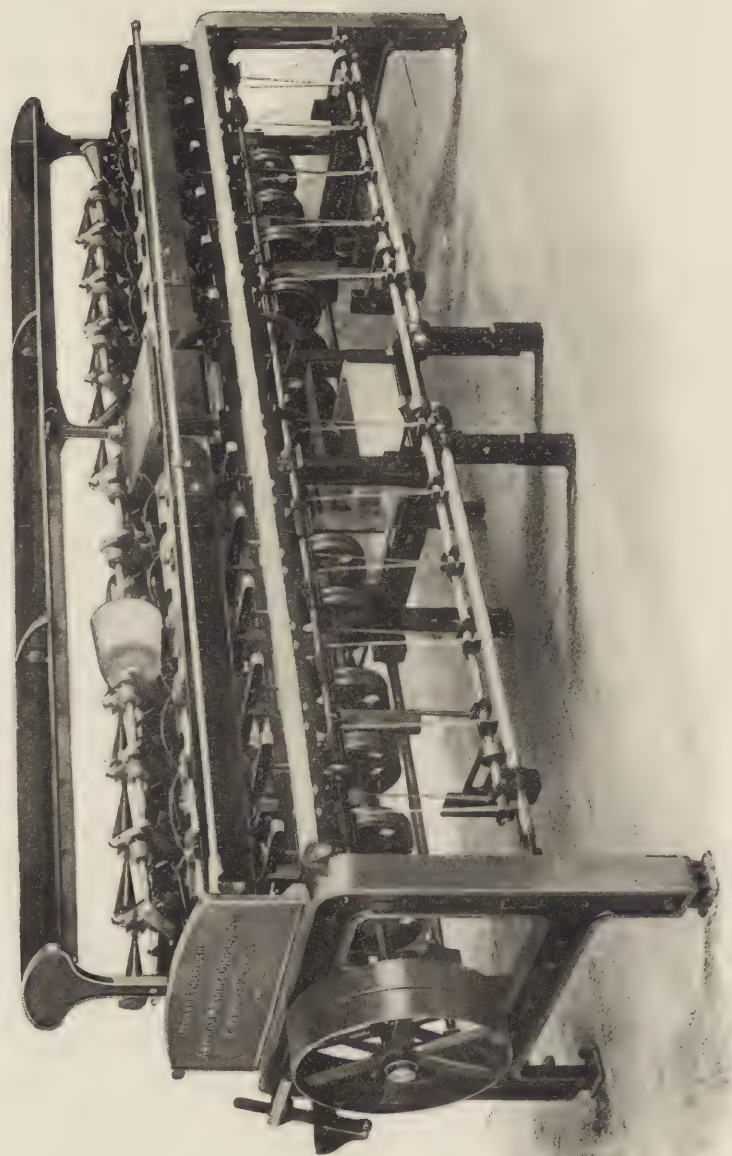
This number by no means represents all the artificial dyestuffs. Thousands are upon the market, but examination will show that many, though sold under entirely different names, are identical. Malachite Green, for instance, has no less than fifteen different names assigned to it by different manufacturers. Many others will be found to be mixtures of two or more distinct colors.

Many dyestuffs have been rendered obsolete by the introduction of newer ones of the same class which are either cheaper or faster and often both. Many others are discovered but, for some reason, are never put upon the market.

Although the number is constantly increasing, and every monthly report publishes many new patents, we may safely say that, at the present time, there are upon the market not more than fifteen hundred dyestuffs that are of different composition.







IMPROVED CONE WINDER  
Howard & Bullough American Machine Co. (Ltd.)

# TEXTILE CALCULATIONS.

## SIZES OF YARNS—NUMBERING.

The sizes of yarns are designated by the terms *cut, run, hank, count, skein, dram, grain, etc.*, all of which are based upon two elementary principles, *i.e.*, weight and length. Each term represents a certain length of yarn for a fixed weight, or *vice versa*; but unfortunately there are different standards of weights and measures, which results in a great deal of confusion. The largest variety of terms is found in the woolen industry. In the United States we have woolen cut, run, grain, etc., when all may be reduced to a common basis. There is no doubt that the adoption of an international standard would benefit the textile industry, but which standard to adopt is a question on which manufacturers disagree.

A simple method would be 1,000 metres as the unit of length, to be called count or number, and the number of units which weigh one kilogram to represent the counts or number of yarn. By this method the counts of the yarn would always show at a glance the number of metres per gram, as

No. 1— 1,000 metres = 1 kg.

No. 2— 2,000 metres = 1 kg.

No.  $2\frac{1}{2}$ —2,500 metres = 1 kg.

### WOOLEN COUNTS.

The simplest method in use at present is the one used in the New England States, in which No. 1 woolen yarn represents 100 yards to the ounce, or 1,600 yards to the pound, as a standard. The number of the yarn is the number of yards contained in one ounce, divided by 100. The yarn is spoken of as so many hundred yards to the ounce. Thus,

No. 4 = 400 yards to 1 ounce.

No.  $4\frac{1}{2}$  = 450 yards to 1 ounce.

No. 5 = 500 yards to 1 ounce.

No.  $5\frac{1}{8}$  = 512.5 yards to 1 ounce.

A comparison of Troy and Avoirdupois weights may be made by the following tables. The Avoirdupois table should be com-

mitted to memory, as it is used very extensively in Textile Calculations.

#### AVOIRDUPOIS WEIGHT.

437.5 grains (gr.)	= 1 ounce (oz.)
16 drams (dr.)	= 1 ounce.
7,000 grains	= 1 pound (lb.)
16 ounces	= 1 pound.
100 pounds	= 1 hundredweight (cwt.)
20 hundredweight	= 1 ton (t.)

NOTE.—25 pounds are sometimes called a quarter.

#### TROY WEIGHT.

24 grains (gr.)	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
5,760 grains	= 1 pound (lb.)
12 ounces	= 1 pound.

It is necessary to familiarize one's self with the standard numbers of the various yarns; also, as in the case of woolen yarns, where different standard numbers are used for the various terms, it is well to be familiar with the standard number of each term, as by this means a great deal of confusion will be avoided.

#### TABLE OF RELATIVE COUNTS OF YARN.

Yarn.	Size.	Standard Number.
Woolen	No. 1 run	= 1,600 yards per lb.
"	No. 1 cut	= 300 " " "
"	No. 1 skein	= 256 " " "
Worsted	No. 1 count	= 560 " " "
Cotton	No. 1 count	= 840 " " "
Linen	No. 1 lea	= 300 " " "
Spun silk	No. 1 count	= 840 " " "

Such fibres as linen, jute, hemp and ramie fibre are usually figured by the lea of 300 yards to the pound. In the grain system the weight in grains of 20 yards designates the counts. Thus, if 20 yards weigh 20, 25, or 30 grains the counts would be No. 20, No. 25 or No. 30 grain yarn respectively.

#### SILK COUNTS.

*Spun Silk* is based upon the same system as cotton, *i.e.*, hank of 840 yards, and the number of such hanks which weigh one pound denotes the counts.

NOTE.—Silk that has been re-manufactured or re-spun is called spun silk.



*Dram Silk.* The system adopted in the United States for specifying the size of silk is based on the weight in drams of a skein containing 1,000 yards. Thus a skein which weighs 5 drams is technically called 5-dram silk. The number of yards of 1-dram silk in a pound must accordingly be  $16 \times 16 \times 1,000$  or 256,000.

NOTE.—1,000 is multiplied by  $(16 \times 16)$  because there are 16 drams in one ounce and 16 ounces in one pound.

*Tram Silk* is based on a system in which 20,000 yards per ounce is used as a standard.

#### WORSTED COUNTS.

This system is based upon the hank of 560 yards, the counts being determined by the number of such hanks contained in one pound of yarn.

No. 1 = 560 yards in 1 pound.

No. 2 = 1,120 yards in 1 pound.

No. 3 = 1,680 yards in 1 pound.

#### COTTON COUNTS.

Cotton is based upon the hank of 840 yards, and the number of such hanks which weigh one pound denotes the counts. The following tables are used when calculating cotton yarns:

$1\frac{1}{2}$  yards = the circumference of reel, or 1 wrap.

120 yards = 1 lea or 80 wraps of the reel.

840 yards = 7 leas or 1 hank.

No. 1 cotton = 840 yards in 1 pound.

No. 2 cotton = 1,680 yards in 1 pound.

No. 3 cotton = 2,520 yards in 1 pound.

**Linen and Similar Fibres** such as *jute*, *hemp*, *ramie fibre*, and *China grass* are numbered by using as a base the lea of 300 yards; the number of such leas which weigh one pound being the counts.

No. 1 = 300 yards in 1 pound.

No. 2 = 600 yards in 1 pound.

No. 3 = 900 yards in 1 pound.

**English Woolen or Skein System.**—This system is based upon the skein of 256 yards, the number of such skeins which weigh one pound being the counts. In England the yarn is spoken of as so many yards to the dram, or so many skeins, which is the

same thing when referring to its size. Thus 6 skeins or 6 yards to the dram; 10 skeins or 10 yards to the dram.

No. 1 = 256 yards to the pound.

No. 2 = 512 yards to the pound.

No. 3 = 768 yards to the pound.

The standard weight is one dram, and the number of yards to that weight is regulated according to requirements.

**The Philadelphia or Cut System** is based upon the cut of 300 yards, the number of such hanks which weigh one pound denoting the counts.

No. 1 = 300 yards to the pound.

No. 2 = 600 yards to the pound.

No. 3 = 900 yards to the pound.

**Rule 1.** To find the yards per pound of any given counts of woolen run, woolen cut, worsted, cotton, linen, and spun silk. Multiply the standard number by the given counts.

Example. How many yards per pound in No. 15 cotton, 3 run woolen, No. 20 worsted? No. 15 cotton,  $840 \times 15 = 12,600$  yards. 3 run woolen,  $1,600 \times 3 = 4,800$  yards. No. 20 worsted,  $560 \times 20 = 11,200$  yards.

**Rule 2.** To find the weight of any number of yards of a given counts, the number of yards being given. Divide the given number of yards by the counts  $\times$  the standard number.

Example. What is the weight of 107,520 yards of No. 32 cotton?

$$107,520 \div (32 \times 840) = 4 \text{ pounds.}$$

Find the weight of 12,400 yards of 30's worsted, 11,960 yards of 20 lea linen, and 7,200 yards of  $4\frac{1}{2}$  run woolen.

**Rule 3.** It is often necessary to know the weight in ounces of a small number of yards. Multiply the given number of yards by 16, and divide by the counts  $\times$  the standard number.

Example. What is the weight in ounces of 2,800 yards of No. 20 worsted?

$$(2,800 \times 16) \div (20 \times 560) = 4 \text{ ozs.}$$

The woolen-run system is the most simple of all textile yarn calculations, as 100 yards per ounce = No. 1 run.

**Rule 4.** To find the weight in ounces of a given number of woolen-run yarn. Add two ciphers to the counts and divide into the given number of yards.

Example. What is the weight of 2,700 yards of 2-run woolen?

$$2,700 \div 200 = 13.5 \text{ ozs.}$$

**Rule 5.** Grain System. To find the counts of a woolen thread, the number of yards and weight being known. (The weight in grains which 20 yards weigh designates the counts.) Multiply the given weight by grains in 1 lb. and by 20 yards, and divide by the given number of yards of yarn.

Example. What is the counts of 28,000 yards which weigh 4 pounds?

$$\frac{4 \times 7,000 \times 20}{28,000} = 20 \text{ grains per 20 yards.} \quad \begin{array}{l} 20\text{'s counts.} \end{array} \text{ Ans.}$$

#### EXAMPLES FOR PRACTICE.

1. How many yards of yarn in 1 lb. of each of the following numbers: No. 23 cotton, No. 5 run woolen, No. 32 worsted, No. 22 lea linen, No. 25 spun silk?

2. Obtain the counts of the following yarns: 12,600 yards cotton = 1 lb.; 11,200 yards worsted = 1 lb.; 12,000 yards linen = 1 lb.; 13,440 yards spun silk = 1 lb.

3. How many yards per pound in 4 dram silk, 5 dram silk, and 3 dram silk?

4. Woolen grain system. How many yards per pound in 7 grain woolen, and 5 grain woolen?

5. If 16,800 yards of yarn weigh 1 pound, what counts would represent this length and weight in worsted, cotton, and woolen?

6. The weight of 1,680 yards of worsted is 3 ounces. What is the counts?

7. Find the respective weights of 800 yards, 4,200 yards, and 6,300 yards of (a) 4-run woolen, (b) No. 30 worsted, (c) No. 30 cotton.

8. What is the weight of 4,200 yards of 30's cotton; 3,600 yards of 32's worsted; 1,850 yards of  $2\frac{1}{2}$  woolen?

9. What is the weight of 1,840 yards of  $3\frac{1}{4}$  run woolen yarn, 2,100 yards of  $4\frac{1}{2}$  run, 3,640 yards of  $3\frac{1}{2}$  run?

10. Find the cotton counts of these yarns: 14,000 yards weigh  $3\frac{1}{2}$  pounds; 37,620 yards weigh  $4\frac{1}{4}$  pounds; 29,640 yards weigh 4 pounds.

NOTE.—The terms count, counts, number, numbers, etc., are used when speaking of the size of yarn. They are written in various ways, for instance, No. 1 counts, 1's, No. 1's, and No. 1. All represent the same thing.

### METRIC MEASUREMENTS AND WEIGHTS.

#### Linear Measure.

	1 millimeter	(mm.)
10 millimeters	= 1 centimeter	(cm.)
10 centimeters	= 1 decimeter	(dm.)
10 decimeters	= 1 meter	(m.)
10 meters	= 1 decameter	(decam.)
10 decameters	= 1 hectometer	(hm.)
10 hectometers	= 1 kilometer	(km.)

#### Measures of Weight.

	1 milligram	(mg.)
10 milligrams	= 1 centigram	(cg.)
10 centigrams	= 1 decigram	(dg.)
10 decigrams	= 1 gram	(g.)
10 grams	= 1 decagram	(decag.)
10 decagrams	= 1 hectogram	(hg.)
10 hectograms	= 1 kilogram	(kg.)

The Continental method for worsted is based upon 1,000 metres per kilogram, *e.g.*, No. 1 counts contains  $1,000 \times 1$  metre. No. 2 counts contains  $1,000 \times 2$  metres. No. 3 counts contains  $1,000 \times 3$  metres, etc.

#### TABLE OF EQUIVALENTS.

1 dm.	=	3.937 inches.
1 dm.	=	15.4999 inches.
1 oz.	=	28.35 grams.
1 oz.	=	437.5 grains.
1 gram	=	15.432 grains.
1 kg.	=	2.2046 pounds or 15432.2 grains.
1 m.	=	1.094 yards.
1 m.	=	39.37 inches.
1,000 m.	=	1 kg. or 2.2046 pounds worsted yarn.
1,000 m.	=	1,094 yards.

In the metric system, woolen counts are based on the same principle as worsted counts, that is, 1,000 metres of No. 1 woolen



weigh 1 kg. or 1,000 grams. This also applies to cotton, linen, silk, jute, etc.

It will be seen from this that the metric system possesses a great advantage over the many varied systems now in use, inasmuch that it is simpler in calculations, decimals doing away with the more complicated fractions of the English system (such as  $\frac{5}{8}$ ,  $\frac{13}{16}$ ,  $\frac{27}{32}$ ,  $\frac{39}{64}$ , etc.), and the uniformity of difference between kilograms, hectograms, decagrams, etc., is simpler than the complex system of tons, hundred-weights, pounds, ounces, drams, and grains.

To reduce kilograms to grams, it is only necessary to multiply the given number by 1,000, while to reduce from pounds to drams in English the given number must be multiplied by  $16 \times 16$ . With metric numbers the difference may be easily computed. Taking 2.25 kg. of yarn and wishing to find the weight in grams, the following simple process is all that is required:

$$2.25 \times 1,000 = 2,250 \text{ grams.}$$

This weight represents approximately 4 pounds 8 ounces, and wishing to find the weight in drams the following complicated equation is necessary:

$$4\frac{1}{2} \times 16 \times 16 = \text{drams.}$$

Another advantage of the metric system is that while a No. 1 in the English system equals 1,600 yards woolen, 560 yards worsted, 840 yards cotton, 300 yards linen, etc., to the pound, in the metric system a No. 1 count has 1,000 metres to the kilogram in every variety of yarn, which gives a simple basis of comparison between the yarns.

#### THROWN SILK.

The Continental Europe system of numbering thrown silk is based upon the hank of 400 French ells. The skein or hank is 476 metres, or 520 yards, and the weight of this hank in deniers denotes the counts.

$$533.33 \text{ deniers equal 1 ounce.}$$

If 1 hank of the above length weighs 10 deniers, the counts equal No. 10 denier.

Approximately No. 1 denier =  $533\frac{1}{3} \times 520 = 277,333$  yards per ounce.

No. 40 denier =  $(533\frac{1}{8} \times 520) \div 40 = 6,933\frac{1}{8}$  yards per ounce.

No. 60 denier =  $(533\frac{1}{8} \times 520) \div 60 = 4,622\frac{2}{3}$  yards per ounce.

### CHANGING THE COUNTS OF YARNS.

The three great fibres, wool, worsted, and cotton, are mixed to a large extent. There are goods composed of woolen filling and cotton warp, worsted filling and cotton warp, woolen and worsted filling combined with cotton warp, and also woolen and worsted warps combined with cotton and woolen fillings; so it is important that the calculations pertaining to each should be thoroughly understood. The calculations in this work are directed towards these requirements. There are shorter methods of calculation which may be used by those fully conversant with the various particulars concerning textile manufactures, but it matters little which system is used if it is simple and reliable.

#### Changing the Counts of one System of Yarn into the Equivalent Counts of Another System of Yarn.

**Rule 6.** To change cotton counts into woolen runs. Multiply 840 by the known cotton counts and divide by 1,600, the standard yards per pound of No. 1 run woolen.

Example. What is the size of a woolen thread equivalent to a 20's cotton?

$$(20 \times 840) \div 1,600 = 10\frac{1}{2} \text{ run woolen.}$$

**Rule 7.** To change cotton counts into worsted counts. Multiply 840 by the known cotton counts, and divide by 560, the standard yards per pound of No. 1 worsted counts.

Example. What is the equivalent in a worsted thread to a 30's cotton?

$$(30 \times 840) \div 560 = 45\text{'s worsted.}$$

**Rule 8.** To change woolen runs into worsted counts. Multiply 1,600 by the known woolen runs, and divide by 560, the standard yards per pound of No. 1 worsted counts.

Example. What is the equivalent in a worsted thread to a 7 run woolen?

$$(7 \times 1,600) \div 560 = 20\text{'s worsted.}$$

**Rule 9.** To change woolen runs, worsted counts, and cotton counts into their equivalents in linen or Philadelphia cuts. Multiply by the woolen, worsted, or cotton standard, and divide

by 300, the standard number of yards which equals 1 lea linen and 1 cut woolen.

Example. What are the equivalents in linen counts to a 3 run woolen, 20's worsted, and 24's cotton?

$$(3 \times 1,600) \div 300 = 16 \text{ lea linen.}$$

**Rule 10.** To change woolen, worsted, linen, or cotton counts to their equivalents in the grain system. Multiply 7,000 grains by 20 (the yards representing the grain standard) and divide by the standard of the other yarn.

Example. What is the equivalent in the grain system to a 20's cotton?

$$\frac{7,000 \times 20}{20 \times 840} = 8.33 \text{ counts.}$$

What is the equivalent in the grain system of the following yarns, 24's worsted, 4 run woolen, 16 lea linen?

**Rule 11.** To change woolen, worsted, linen, or cotton counts to their equivalents in the dram system. Multiply the given weight by drams per pound and by the yards in one dram, then divide by the given length of yarn.

Example. What is the equivalent in the dram system to a No. 30 cotton?

$$\frac{1 \times 256 \times 1,000}{30 \times 840} = 10.15.$$

Find the equivalent in the dram system to 24's cotton,  $4\frac{1}{4}$  run woolen, 30's worsted.

**Rule 12.** To change woolen, worsted, linen, and cotton counts to their equivalents in the denier system. Multiply the yards in one hank (520), deniers in one ounce ( $533\frac{1}{3}$ ), and ounces in 1 pound (16) together and divide the product by the length of 1 pound of yarn of the known counts.

Example. What is the equivalent in the denier system to a 30's worsted?

$$\frac{520 \times 533\frac{1}{3} \times 16}{30 \times 560} = 264.12 \text{ denier yarn.}$$

**Rule 13.** To change metric counts to English counts. The number of metres in one kilogram (1,000) multiplied by the

number of inches in one metre (39.37) will give the total number of inches. This divided by the inches in one yard (36) will give the total number of yards, and again divided by the weight of 1 km.  $\times$  the standard number will give the English counts, or constant.

Solution:

$$\begin{array}{rcl} \frac{1,000 \times 39.37}{36 \times 560 \times 2.205} & = & .885 \text{ worsted count.} \\ \frac{1,000 \times 39.37}{36 \times 840 \times 2.205} & = & .590 \text{ cotton and spun silk constant.} \\ \frac{1,000 \times 39.37}{36 \times 1,600 \times 2.205} & = & .3099, \text{ say } .31, \text{ woolen constant.} \\ \frac{1,000 \times 39.37}{36 \times 300 \times 2.205} & = & 1.653 \text{ linen and woolen cut constant.} \end{array}$$

The English	.885	is equal to a No. 1 metric worsted.
" "	.590	" " " " No. 1 " cotton or spun silk.
" "	.310	" " " " No. 1 " woolen.
" "	1.653	" " " " No. 1 " linen, etc.

#### Proof

$$\begin{array}{rcl} 1 \text{ metre} & = & 1.094 \text{ yards.} \quad 1 \text{ kilogram} = 2.205 \text{ pounds.} \\ 1,000 \text{ metres No. 1} & = & 1 \text{ kilogram} = 2.205 \text{ pounds.} \\ 1,000 \text{ metres} & = & 1,094 \text{ yards.} \\ 1,094 \div 2.205 & = & 496.1 \text{ yards per pound.} \\ 496.1 \div 560 & = & .885 \text{ worsted constant.} \\ 496.1 \div 840 & = & .590 \text{ cotton "} \\ 496.1 \div 1,600 & = & .310 \text{ woolen "} \\ 496.1 \div 300 & = & 1.653 \text{ linen "} \end{array}$$

**Rule 14.** The English count divided by the constant will give the metric count.

Example. English 20's cotton  $\div .590 = 33.89$  metric cotton counts.

Find the metric counts of 24's worsted, 6 run woolen, and 18 lea linen.

**Rule 15.** The metric count multiplied by the constant will give the English count.

$$.310 \times 20 \text{ metric woolen} = 6.2 \text{ run woolen.}$$

Find the counts in English of the following metric counts: 23.6 cotton, 28.2 worsted, and 16 woolen. .

#### TWISTED, PLY, AND COMPOUND YARNS.

Yarns spun from different fibers are frequently twisted together for decorative purposes, and also for strength, *e.g.*, silk



to cotton, worsted to woolen, etc. As yarns may be spun in one place and consigned for use in localities where different systems of numbering yarns are in use, it is necessary to change any given number into the equivalent count of some other denomination.

*Worsted and cotton yarns* are usually numbered according to the count of the single yarn, with the number of ply, threads, or folds, placed at the left, or before it. Thus 2-40's cotton yarn indicates that the yarn is composed of two threads of 40's single, making a two-fold or two-ply yarn of 20 hanks to the pound, and must be considered as representing 20 times 840 yards; but when written 40's or 1-40's it represents 40 hanks or 40 times 840 yards to the pound.

*Spun silk yarns* are generally two or more ply, and the number of the yarn always indicates the number of hanks in one pound. The number of ply is usually written after the hanks per pound. Thus 60-2 or 60's-2 spun silk indicates that the yarn is 60 hanks to the pound composed of two threads of other counts.

*Two-ply woolen yarns* are usually designated "Double and Twist" yarns, thus, 6 run black and white "D & T" would mean that one black thread of 6 run and one white thread of 6 run have been doubled and twisted, and represent a thread which is equivalent to a 3 run minus the take-up.

When two or more single threads are twisted together, the result is a heavier yarn. It is necessary then to find the number of hanks or skeins per pound of the combined thread, but it must be understood that two threads, 20 yards long, twisted together will be much shorter than the original two threads. This can be proved by twisting together two threads of a given length, weighing them, and again measuring the twisted thread, or by obtaining two threads of the original yarn of the exact length of the twisted yarn and comparing their weights. This process is known as *finding the equivalent or resultant counts*.

**Ply yarns composed of threads of equal counts.** The new count is found by dividing the given counts by the number of ply or threads twisted together, 2-ply 60's = No. 30, written 2-60's;

3-ply 60's = No. 20, written 3-60's; 4-ply 60's = No. 15, written 4-60's.

Assuming there is no variation in the take-up of each yarn during twisting, equal length of each material will be required.

It frequently occurs in fancy novelty yarns that threads of *unequal size* are twisted together. If a No. 60 thread and a No. 40 thread are twisted together, the count of the doubled thread will not be the same as if two threads of No. 50 have been twisted. For instance, when 60 hanks of 60's worsted are used 60 hanks of 40's worsted will also be used, and when these have been twisted together there are still only 60 hanks, but 60 hanks of the former count weigh one pound, while 60 hanks of the latter weigh  $1\frac{1}{2}$  pounds, consequently the 60 hanks of twisted threads equal 2.5 pounds.

**Rule 16.** The product of the given counts divided by their sum, gives the new count of twisted yarn.

$$\frac{60 \times 40}{60 + 40} = \frac{2,400}{100} = \text{No. 24 worsted.}$$

Some allowance must be made for take-up or contraction in twisting, but this will vary with the number of turns of twist per inch in the yarn and the diameter of the threads.

Take-up, contraction, and shrinkages are not considered in these examples.

**Rule 17.** When three or more unequal threads are twisted together, the counts of the resulting twist thread is found by dividing the highest count by itself and each of the given counts in succession; the quotient in each case representing the proportionate weight of each thread. Then dividing the highest counts by the sum of the quotients, the answer will be the new counts.

Example. Find the counts of a 3-ply thread composed of one thread each of 20's, 30's, and 60's cotton.

$$\begin{array}{l} 60 \div 60 = 1 \\ 60 \div 30 = 2 \quad 60 \div 6 = 10's, \text{ count of 3-ply cotton thread.} \\ 60 \div 20 = 3 \\ \hline 6 \end{array}$$

Find the counts of a 3-ply thread composed of one thread each of 120's, 60's, and 40's cotton.

**Compound Thread Composed of Different Materials.** It is obvious that when threads composed of different materials are twisted together it is necessary to first reduce all to the denomination of the yarn system in which it is required.

Suppose a compound twist thread is made up of one thread of 24's black worsted, one thread 16's red cotton, and one thread 8's green cotton. Find the equivalent counts in worsted as follows:

$$840 \times 16 = 13,440 \div 560 = 24 \text{ worsted.}$$

$$840 \times 8 = 6,720 \div 560 = 12 \quad "$$

$$24 \div 24 = 1$$

$$24 \div 24 = 1 \quad 24 \div 4 = 6's, \text{ counts of 3-ply thread in worsted.}$$

$$24 \div 12 = 2$$

$$\underline{4}$$

What is the equivalent in a single woolen thread of a 3-ply yarn composed of 10.5 run woolen, 20's cotton, and 30's worsted?

$$840 \times 20 = 16,800 \div 1,600 = 10.5.$$

$$560 \times 30 = 16,800 \div 1,600 = 10.5.$$

$$10.5 \div 3 = 3.5 \text{ run woolen.}$$

#### EXAMPLES FOR PRACTICE.

1. If a thread of 20's and a thread of 40's single worsted be twisted together, what is the resultant counts?

2. What is the resultant counts (*a*) of 30's and 60's cotton twisted together, (*b*) of 30 lea and 60 lea linen twisted together, and (*c*) of 30's and 60's worsted twisted together?

3. A 3-ply thread is made by twisting the following yarns: one thread  $10\frac{1}{2}$  run woolen, one thread 30's worsted, one thread 20's cotton. What would be the equivalent counts of the compound thread in (*a*) single cotton, (*b*) woolen cut, (*c*) single worsted, and (*d*) woolen run?

4. Give the resultant counts of 36's, 45's, and 54's worsted yarn twisted together.

5. How many hanks would there be in 1 pound of 2-ply yarn made by twisting one thread of 32's cotton and one thread 44's cotton together?

6. Given 36 metric cotton counts, find the equivalent counts when twisted with a 60-2 spun silk, the answer to be in cotton counts.

7. What would be the resultant counts in spun silk of 30's worsted, 20-2 spun silk twisted together?

8. Find the equivalent counts of 20's, 32's, and 50's worsted twisted together.

9. A thread is composed of two threads 40's worsted, and one thread 80's-2 spun silk. Find the equivalent counts in cotton.

10. Find the resultant counts of 70's, 60's, 40's, and 20's cotton twisted together.

### FANCY AND NOVELTY YARNS.

Novelty yarns, such as knop, spiral, loop, corkscrew, chain, etc., are made from various lengths of threads, and consequently the previous rules will not apply in all cases. If there is no variation in lengths, the same number of hanks will be required of each kind of yarn, but when lengths vary, the counts of the twisted threads will also vary according to the several modifications of take-up in the material used.

For example, if it is desired to make a fancy yarn from three different counts of yarn, say 40's, 30's, and 20's cotton, the take-up in each case being equal, what length and weight of each material is necessary?

**Rule 18.** First, find the necessary number of pounds of each yarn to give equal length, by dividing the highest counts by itself and the counts of each of the others, the result being the relative weight required of each.

$$\begin{aligned} &40 \div 40 = 1 \text{ pound.} \\ \text{(A)} \quad &40 \div 30 = 1\frac{1}{3} \text{ pounds.} \\ &40 \div 20 = 2 \text{ pounds.} \end{aligned}$$

The respective weights of the yarn multiplied by their counts will give the required number of hanks of each.

$$\begin{aligned} &1 \text{ pound} \times 40 = 40 \text{ hanks of 40's cotton.} \\ \text{(B)} \quad &1\frac{1}{3} \text{ pounds} \times 30 = 40 \text{ hanks of 30's cotton.} \\ &2 \text{ pounds} \times 20 = 40 \text{ hanks of 20's cotton.} \end{aligned}$$

It is obvious that if a certain length of twist is required the yarns used must be of approximately the same length, whatever the counts, but when the take-up varies, the conditions are more or less complicated.

Suppose a novelty yarn is made by twisting two threads of 40's red cotton, one thread of 30's green cotton, and one thread



of 20's black cotton, and the relative lengths of material used are 7, 5, and 4 inches respectively. Find the counts of the combined thread. The last named thread is straight or 100 per cent.

First, find the take-up of each yarn by dividing each relative length by the straight or 100 per cent thread.

$$\begin{array}{rcl} & 7 \div 4 = 1\frac{3}{4} \text{ take-up.} \\ \text{(C)} & 5 \div 4 = 1\frac{1}{4} \quad \text{"} \quad \text{"} \\ & 4 \div 4 = 1 \quad \text{"} \quad \text{"} \end{array}$$

The number of hanks of each (obtained by A and B) multiplied by the take-up (obtained by C), will give the number of hanks of the respective yarns necessary for the twist yarn.

$$\begin{array}{rcl} 40 \times 1\frac{3}{4} & = & 70 \text{ hanks of No. 40} \\ 40 \times 1\frac{1}{4} & = & 70 \text{ hanks of No. 40} \\ 40 \times 1\frac{1}{4} & = & 50 \text{ hanks of No. 30} \\ 40 \times 1 & = & 40 \text{ hanks of No. 20} \end{array}$$

and these divided by their relative counts, will give the weight of each.

$$\begin{array}{rcl} 70 \text{ hanks} \div 40 & = & 1.75 \text{ pounds.} \\ 70 \text{ hanks} \div 40 & = & 1.75 \text{ pounds.} \\ 50 \text{ hanks} \div 30 & = & 1.66 \text{ pounds} \\ 40 \text{ hanks} \div 20 & = & 2.00 \text{ pounds.} \\ & & \hline & & 7.16 \text{ pounds.} \end{array}$$

The number of hanks necessary for equal length divided by the sum of their weights will give the count of the combined or resultant thread.

$$40 \div 7.16 = 5.58 \text{ count.}$$

To prove, find the length of each yarn in one hank of the novelty yarn thus,

$$\begin{array}{rcl} 7 \text{ inches No. 40's} & = & 840 \times 1\frac{3}{4} = 1,470 \text{ yards.} \\ 7 \text{ inches No. 40} & = & 840 \times 1\frac{1}{4} = 1,470 \text{ yards.} \\ 5 \text{ inches No. 30} & = & 840 \times 1\frac{1}{4} = 1,050 \text{ yards.} \\ 4 \text{ inches No. 20} & = & 840 \times 1 = 840 \text{ yards.} \end{array}$$

The weight of each being

$$\begin{array}{rcl} \text{No. 40} & = & 1,470 \times 7,000 \div 40 \times 840 = 306.25 \text{ grs.} \\ \text{No. 40} & = & 1,470 \times 7,000 \div 40 \times 840 = 306.25 \text{ grs.} \end{array}$$

$$\text{No. 30} = 1,050 \times 7,000 \div 30 \times 840 = 291.66 \text{ grs.}$$

$$\begin{array}{r} \text{No. 20} = 840 \times 7,000 \div 20 \times 840 = 350.00 \text{ grs.} \\ \hline 1,254.16 \text{ grs.} \end{array}$$

Therefore, if one hank of the novelty yarn weighs 1,254.16, the counts will be  $7,000 \div 1,254.16 = 5.58$  counts, the same as given in the above example.

#### WEIGHT OF MATERIAL TO PRODUCE A GIVEN WEIGHT.

The question of determining the actual quantity of each kind of yarn required to produce a given weight of ply or folded yarn is an important item in textile calculations, and may assume a variety of forms. The simplest form is to assume that the counts of the yarns and the total weight are given, and it is required to find the weight or quantity of each yarn to produce the total weight. For convenience, assume that the counts of the yarns to be twisted together are 30's and 20's respectively, and that the total weight required is 1,000 pounds.

The first step is to ascertain the counts of the folded yarn resulting from this combination, after the manner already described, thus

$$\frac{30 \times 20}{30 + 20} = 12's.$$

After this the process is quite simple, being a question of proportion, or, as each count in succession is to the count of the folded yarn, so is the total weight to the required weight. To make it clear, the counts of single yarns are 30's and 20's respectively, the folded yarn is 12's, and the total weight 1,000 pounds, then

$$30 : 12 :: 1,000 : \times = 400 \text{ pounds of 30's yarn.}$$

$$20 : 12 :: 1,000 : \times = 600 \text{ pounds of 20's yarn.}$$

So that the whole is reduced to the simplest possible form.

**Rule 19.** To find the weight of each material required to produce a given weight of a double and twisted or compound yarn. First ascertain the counts of the two yarns twisted together after the manner laid down in Rule 16, then as each count in succession is to the compound yarn, so is the total weight to the weight required.

Example. What amount of each kind of yarn is required to produce 1,000 pounds of twist yarn made from 60's and 80's cotton?

$$\begin{array}{r} 60 \times 80 \\ \hline 60 + 80 \end{array} = 34\frac{2}{7}$$

$$\begin{array}{rcl} 60 : 34\frac{2}{7} :: 1,000 & = & 571\frac{3}{7} \\ 80 : 34\frac{2}{7} :: 1,000 & = & 428\frac{4}{7} \\ & & \hline & & 1,000 \end{array}$$

Proof.

$$80 \times 428\frac{4}{7} = 67,200 \text{ yards} \times 428\frac{4}{7} = 28,800,000 \text{ yards.}$$

$$60 \times 571\frac{3}{7} = 50,400 \text{ " } \times 571\frac{3}{7} = 28,800,000 \text{ yards.}$$

The following rule is used in many mills:

- (a)  $\frac{\text{Given weight} \times \text{lower count}}{\text{Sum of the two counts}} = \text{Weight of the higher count.}$
- (b)  $\frac{\text{Given weight} \times \text{higher count}}{\text{Sum of the two counts}} = \text{Weight of lower count.}$

Example. What amount of material will be required for each thread to produce 250 pounds of double and twist yarn made from 32's and 40's worsted ?

$$250 \times 32 \div 72 = 111\frac{1}{3} \text{ pounds, weight of higher count.}$$

$$250 \times 40 \div 72 = 138\frac{2}{3} \text{ pounds, weight of lower count.}$$

Proof.

$$32 \times 111\frac{1}{3} = 17,920 \times 138\frac{2}{3} = 2,488,888\frac{2}{3} \text{ yards.}$$

$$40 \times 138\frac{2}{3} = 22,400 \times 111\frac{1}{3} = 2,488,888\frac{2}{3} \text{ yards.}$$

When only two counts are required, the above methods are simple and very useful, but when three or more counts are twisted together, some other method of solution is necessary to find the weight of each material to produce a given weight.

**Rule 20.** First find the relative weight of each kind of yarn by dividing the highest count by its own number and the other numbers in succession, then multiply the given weight by the relative weight of each count, and divide by the sum of the relative weights. The quotients will be the weights of each kind of yarn.

Example. 533 pounds of twist to be made from 20's, 30's, and 40's; required the weight of each.

$$40 \div 40 = 1 \times 533 = 533 \div 4\frac{1}{3} = 123 \text{ pounds.}$$

$$40 \div 30 = 1\frac{1}{3} \times 533 = 710\frac{2}{3} \div 4\frac{1}{3} = 164 \text{ pounds.}$$

$$\begin{array}{r} 40 \div 20 = 2 \times 533 = 1,066 \div 4\frac{1}{3} = 246 \text{ pounds.} \\ \hline 4\frac{1}{3} \qquad \qquad \qquad 533 \end{array}$$

Example. 120 pounds of twist is required of 30's, 40's, and 60's worsted. What weight of each count will the compound thread contain?

**To Find the Relative Weight of Each Thread in a Compound Yarn When Lengths Vary.** By Rule 18, both the resultant counts and the relative weight of the two yarns may be obtained.

Example. A fancy loop yarn is composed of 12's and 60's worsted, 6 inches of the latter being required to 3 inches of the former. What weight of each will be required to produce 200 pounds of twist, and what number of hanks of the loop yarn will weigh 1 pound?

NOTE—The length of 60's is double that of the unit length of 12's.

$$60 + 60 = 120 \div 60 = 2 \text{ pounds.}$$

$$60 + 0 = 60 \div 12 = 5 \text{ "}$$

$$\underline{7 \text{ pounds.}}$$

or

$$60's = 6 \div 3 = 2 \times 60 = 120 \text{ hanks.}$$

$$12's = 6 \div 6 = 1 \times 60 = 60 \text{ "}$$

$$120 \div 60 = 2 \text{ pounds of 60's.}$$

$$60 \div 12 = 5 \text{ pounds of 12's.}$$

60 hanks of twist yarn weigh 7 pounds.  $60 \div 7 = 8.57$   
hanks = 1 pound, using Rule 20 as in previous example.

$$(a) \quad \frac{200 \times 2}{7} = 57\frac{1}{7} \text{ pounds of 60's.}$$

$$(b) \quad \frac{200 \times 5}{7} = 142\frac{6}{7} \text{ pounds of 12's.}$$

Example. A loop yarn is composed of 2 threads of 8's worsted and 1 thread of 12's worsted; 21 inches of the former are required to 14 inches of the latter. What weight of each will be required to produce 150 pounds of twist, and what number of hanks per pound will the loop yarn contain?

$$12 + (\frac{1}{2} \text{ of } 12) = 18 \div 8 = 2.25 \text{ pounds.}$$

$$12 + (\frac{1}{2} \text{ of } 12) = 18 \div 8 = 2.25 \text{ "}$$

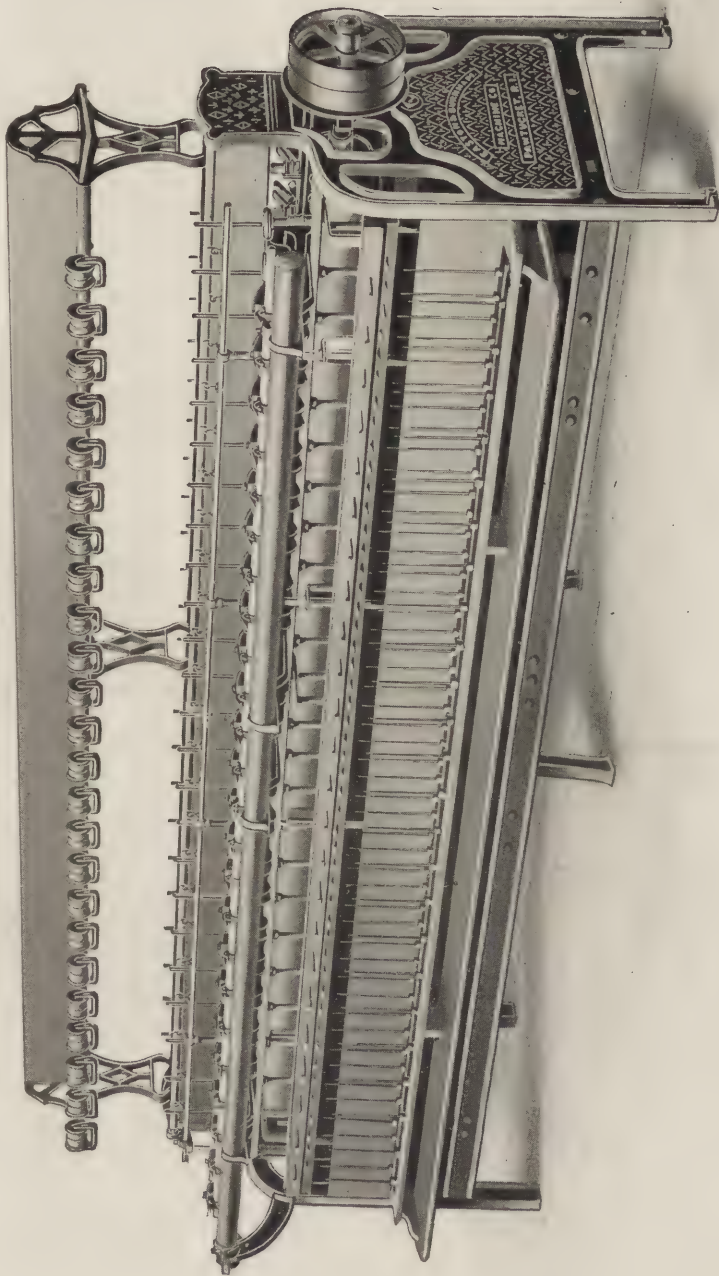
$$12 + 0 = 12 \div 12 = 1. \text{ "}$$

$$\underline{5.5 \text{ pounds.}}$$

Twelve hanks of loop yarn weigh 5.5 pounds.

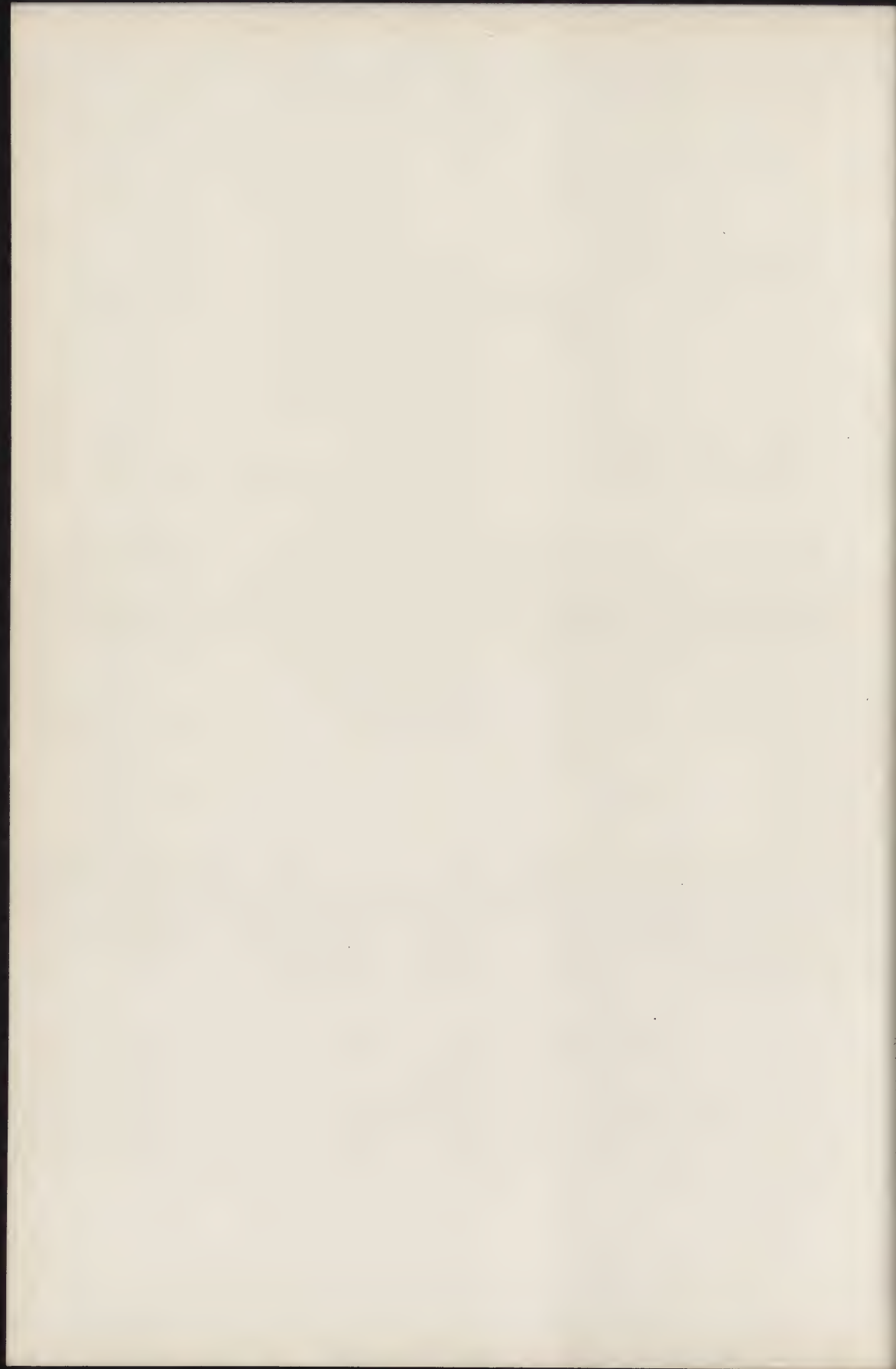
$$12 \div 5.5 = 2\frac{2}{11} \text{ hanks per pounds or loop counts.}$$





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$$\text{and } 150 \times 2.25 \div 5.5 = 61\frac{4}{11} \text{ of 8's worsted.}$$

$$150 \times 2.25 \div 5.5 = 61\frac{4}{11} \text{ of 8's "}$$

$$150 \times 1 \div 5.5 = 27\frac{3}{11} \text{ of 12's "}$$

150 pounds of loop yarn.

**To Find the Weight of a Given Yarn to be Twisted With a Yarn, the Weight and Counts Being Known.** The problem may now be put in a different way. There may be a given quantity of one of the yarns, and it is required to find what weight will be necessary to twist with it and just use it up. This is obviously the reverse of the above proceeding, and at once resolves itself into a simple proportion, being dependent only upon the relative counts; thus 20's and 30's are to each other as 2 is to 3, and, as the higher number is the lighter yarn, the proportion must be inverse.

Supposing then, that there are 400 pounds of 30's yarn and it is required to find how much 20's would be necessary to twist with it. The problem would be as  $20 : 30 :: 400 : \times = 600$ . Proof: 600 pounds of 20's would contain  $600 \times 20 = 12,000$  hanks, and 400 pounds of 30's would contain 12,000 hanks, so that the length of each would be equal.

**Rule 21.** Multiply the given weight by its counts and divide by the counts of the required weight and the quotient will be the weight required.

Example. If you have 480 pounds of 30's cotton, what weight of 26's cotton would be required to twist with it to work it all up, and what will be the counts of the resulting twist?

$$480 \times 30 \div 26 = 553\frac{11}{13} \text{ pounds.}$$

$$\frac{26 \times 30}{26 + 30} = 13\frac{13}{14} \text{ counts.}$$

Proof.

$$480 \times 30 = 14,400 \text{ hanks.}$$

$$553\frac{11}{13} \times 26 = 14,400 \text{ hanks.}$$

#### AVERAGE COUNTS.

When average counts are required, it is assumed that the threads are contiguous in the woven fabric and retain their respective individualities, *e.g.*, when two or more threads of

various sizes are used side by side in a fabric. It is frequently necessary to determine the average counts of these threads, that is, the counts which will represent the same weight and length for the combination of several yarns employed in the woven fabric. Suppose a cloth is woven with the pattern as follows: 2 threads of 60's cotton, and 1 thread of 20's cotton. What is the average counts?

**Rule 22.** Multiply the high count by the number of threads of each count in one repeat of the pattern.

$$60 \times 2 = 120 \text{ hanks.}$$

$$60 \times 1 = 60 \quad "$$

Divide each product separately by the given counts.

$$120 \div 60 = 2 \text{ pounds.}$$

$$\begin{array}{r} 60 \div 20 = 3 \quad " \\ \hline 180 \qquad \qquad 5 \text{ pounds.} \end{array}$$

Divide the total number of hanks by the sum of these quotients.

$$180 \div 5 = 36 \text{ average counts.}$$

**Rule 23.** To find the average counts when any number of threads of different counts are used in the same cloth. Divide the product of the counts by the sum of the unequal counts, then multiply by the number of threads in one repeat of the pattern. The answer is the average counts.

A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = 56} = 11.45 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.



A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = 56} = 11.43 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads 40's black cotton, and 1 thread 16's red cotton. Find the average counts.

$$40 \times 2 = 80$$

$$80 \div 40 = 2$$

$$40 \times 1 = 40$$

$$40 \div 16 = 2.5$$

$$\underline{120}$$

$$\underline{4.5}$$

$120 \div 4.5 = 26.66$  average counts.

$$40 \div 40 = 1$$

$$40 \div 40 = 1$$

$$40 \div 16 = 2.5$$

$$\underline{4.5}$$

$$40 \div 4.5 = 8.88$$

$$8.88 \times 3 = 26.64 \text{ average counts.}$$

A pattern is composed of 4 threads of 80's white cotton, 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.

$$80 \div 80 = 1 \times 4 \text{ threads} = 4$$

$$80 \div 40 = 2 \times 2 \text{ threads} = 4$$

$$80 \div 16 = 5 \times 1 \text{ thread} = 5$$

$$\underline{7}$$

$$\underline{13}$$

$$\frac{80 \times 7}{13} = 43\frac{1}{3} \text{ average counts.}$$

Proof. Obtain the weight of one hank of each count given, then the weight of an average hank with the threads of the proportion given, and find what would be the counts of that weight.

$$1 \text{ hank of } 80\text{'s} = 7,000 \div 80 = 87.5 \text{ grains.}$$

$$1 \text{ hank of } 40\text{'s} = 7,000 \div 40 = 175. \text{ grains.}$$

$$1 \text{ hank of } 16\text{'s} = 7,000 \div 16 = 437.5 \text{ grains.}$$

$$80 = 87.5 \times 4 = 350$$

$$40 = 175. \times 2 = 350$$

$$16 = 437.5 \times 1 = 437.5$$

$$\underline{7} \quad \underline{1137.5} \text{ grains.}$$

$$1137.5 \div 7 = 162.5 \text{ grains average.}$$

$$7,000 \text{ grains} \div 162.5 = 43\frac{1}{3} \text{ average counts.}$$

#### UNKNOWN COUNT IN A COMPOUND OR TWIST THREAD.

Occasionally, it happens that a manufacturer or spinner has given to him the counts of a novelty or fancy twist yarn, also the counts of one or more of the threads of which it is composed. It then becomes necessary to find the size of the unknown thread which, together with the known counts, makes the compound twist yarn.

**Rule 24.** To find the required counts of a single yarn to be twisted with another, the counts of which is already known, to produce a compound or twist thread of a known count. Multiply the counts of the known single thread by the counts of the compound or twist thread, and divide the product by the known counts of the single thread minus the known counts of the compound thread. The quotient will be the counts of the required single thread.

**Example.** Having some yarn in stock, the counts of which is 1-30's cotton, it is desired to produce a compound or twist thread equal to 1-12's cotton. Find the count of the required thread.

$$\frac{30 \times 12}{30 - 12} = \frac{360}{18} = 20\text{'s required thread.}$$

**Proof.** 
$$\frac{30 \times 20}{30 + 20} = \frac{600}{50} = 12\text{'s twist or compound thread.}$$

In the cotton trade, worsted and silk threads are twisted with cotton. In the worsted trade, cotton and silk threads are twisted with worsted. In the woolen trade, cotton, silk, and worsted threads are twisted with woolen.

For the cotton trade, transfer the worsted and silk to cotton counts. For the worsted trade, transfer the cotton and silk to worsted counts. For the woolen trade, transfer the cotton, silk, and worsted to woolen numbers.

**Rule 25.** Two known single thread, a third thread required to produce a known compound thread. First find the size of the two known threads twisted together, then proceed as in previous examples.

Find the counts of the third thread to twist with a 1-30's cotton thread, and 1-60's cotton thread, to produce a three-ply thread equal to a 12's cotton.

$$\frac{60 \times 30 = 1,800}{60 + 30 = 90} = 20's \text{ cotton.}$$

$$\frac{20 \times 12 = 240}{20 - 12 = 8} = 30's \text{ required.}$$

Proof. Three-ply twist, 60's, 30's and 30's.

$$60 \div 60 = 1$$

$$60 \div 30 = 2 \quad 60 \div 5 = 12's \text{ 3-ply thread.}$$

$$60 \div 30 = 2$$

$$\underline{5}$$

Find the size of a worsted thread to twist with a 1-30's cotton. to produce a two-ply thread equal to a 2-30's cotton.

$$2-30's = 1-15's \text{ cotton.}$$

$$\frac{30 \times 15 = 450}{30 - 15 = 15} = 30's \text{ cotton.}$$

$$840 \times 30 = 25,200$$

$$\frac{25,200}{560} = 45's \text{ required worsted thread.}$$

#### EXAMPLES FOR PRACTICE.

1. A pattern is composed of 4 threads of 80's black worsted, 3 threads of 60's white worsted, and 1 thread of 16's blue worsted. Find the average counts.

2. Find the counts of the required thread to twist with a 40's cotton to produce a compound thread equal to a 24's.

3. Find what counts twisted with 24's cotton would produce a compound thread equal to a 9's cotton.

4. Required the counts of a spun silk thread to twist with a 20's cotton and a 30's worsted to produce a 3-ply thread equal to a  $3\frac{1}{2}$ -run woolen.

5. Find the counts of a third thread to twist with a 30's cotton, and a 20's cotton to produce a 3-ply thread equal to a 12's cotton.

#### CONSTANTS.

In figuring textiles there are many numbers which are constantly repeated, thus making it desirable to dispense with some of them by cancelling one into the other, for instance:  $7,000 \div 840$   $7,000 \div 1,600$ ,  $7,000 \div 560$ , etc.

These numbers are also used in reverse order, one being multiplied by, or divided into, the other very frequently. To simplify these calculations, the following constants have been worked out and will prove a valuable reference table:

**Long Method First Constant Second Constant.**

Woolen	$7,000 \div 1,600 = 4.375 \div 36 = .1215$
Worsted	$7,000 \div 560 = 12.5 \div 36 = .3472$
Cotton	$7,000 \div 840 = 8.33 \div 36 = .2314$
Linen	$7,000 \div 300 = 23.33 \div 36 = .648$

Woolen	$1,600 \div 7,000 = .228$
Worsted	$560 \div 7,000 = .08$
Cotton	$840 \div 7,000 = .12$
Linen	$300 \div 7,000 = .043$

Frequently the counts of a very small amount of yarn is required, and to obtain the necessary data, a pair of fine grain scales is one of the most necessary pieces of apparatus required in a manufacturer's or designer's office.

Suppose a sample of woolen cloth contains 40 threads per inch and the sample is 2 inches long, then there would be  $40 \times 2 = 80$  inches of yarn, and these threads weigh 2.5 grains. What is the run of the yarn?

**Rule 26.** Multiply the number of inches of yarn by 7,000 (the number of grains in 1 lb.), and divide by the weight (in grains) of the yarn, multiplied by the standard number, and by 36. The answer will be the run of the yarn.

$$\frac{80 \times 7,000}{2.5 \times 1,600 \times 36} = 3.88 \text{ run.}$$

Example. If a sample of cotton cloth 1 inch long has 40 warp threads in 1 inch, and the yarn weighs 2.5 grains, what is the count?

$$\frac{40 \times 7,000}{2.5 \times 840 \times 36} = \text{No. } 3.7037.$$

Explanation. As there are 7,000 grains in 1 lb. and 840 yards of number 1 yarn in 1 lb.  $7,000 \div 840$  gives the number of grains in one yard of number 1 yarn, or  $8\frac{1}{3}$  grains. The constants, as we have 40 warp threads per inch,  $8\frac{1}{3}$  grains, multiplied by 40 gives us the weight in grains of one running yard of number 1 warp one inch in width, or  $333\frac{1}{3}$  grains.



As one square inch of warp weighs 2.5 grains, one running yard one inch wide would weigh  $2.5 \times 36 = 90$  grains. Now, as 90 grains is the actual weight of the yarn, and  $333\frac{1}{3}$  grains the weight of an equal quantity of number 1 yarn, the number of our warp yarn is the number of times the weight of number 1 yarn is greater than the given yarn, or

$$333.33 \div 90 = 3.7037 \text{ cotton counts.}$$

Example. Supposing 12 threads worsted were obtained, each 36 inches long with a total weight of 1 grain, what is the counts? \*

$$\frac{7,000}{560} = 12.5 \text{ grains, the weight of 1 yard of number 1 worsted.}$$

Therefore, if 1 yard of yarn weighs  $12\frac{1}{2}$  grains, the counts are 1's, or if 2, 3, 4, or 5 yards weigh  $12\frac{1}{2}$  grains, the counts are 2's, 3's, 4's, or 5's respectively, or the number of yards of yarn which weigh  $12\frac{1}{2}$  grains is equivalent to the counts in worsted.

Then the counts in the above example would be number  $12\frac{1}{2}$ , because  $12\frac{1}{2}$  yards would be required to weigh  $12\frac{1}{2}$  grains.

If 48 inches of woolen yarn weigh 2 grains, what is the run?

$$\text{Long method. } \frac{48 \times 7,000}{2 \times 1,600 \times 36} = 2.916, \text{ say 2.9 run.}$$

$$\text{First constant. } \frac{48 \times 4.375}{2 \times 36} = 2.916 \text{ run.}$$

$$\text{Second constant. } \frac{48 \times .1215}{2} = 2.916 \text{ run.}$$

If 96 inches of cotton yarn weigh 2 grains, what is the counts?

$$\text{Long method. } \frac{96 \times 7,000}{2 \times 840 \times 36} = 11.10 \text{ counts.}$$

$$\text{First constant. } \frac{96 \times 8.33}{2 \times 36} = 11.10 \text{ counts.}$$

$$\text{Second constant. } \frac{96 \times .2314}{2} = 11.10 \text{ counts.}$$

If 75 inches of worsted yarn weigh 2.5 grains, what is the count?

$$\text{Long method. } \frac{75 \times 7,000}{2.5 \times 560 \times 36} = 10.416 \text{ counts.}$$

\*NOTE—This subject is again taken up in Yarn Testing.

$$\text{First constant. } \frac{75 \times 12.5}{2.5 \times 36} = 10.416 \text{ counts.}$$

$$\text{Second constant. } \frac{75 \times .3472}{2.5} = 10.416 \text{ counts.}$$

### YARN TESTING.

The term "Yarn Testing" means a great deal more than the casual observer in a mill supposes. Failure to test yarn, or imperfect testing may cause serious trouble. It is often necessary to test yarns in a variety of ways, and for different purposes. The most common test, and it may be safely said the only test which is applied in a large number of mills, is to ascertain the counts, but there are instances when the yarn should be tested for *strength, elasticity, evenness, and for quality.*

This latter test in some cases is a difficult one, and the question often arises as to what is meant by quality. As applied to yarns, the term quality is difficult to define briefly and accurately, in fact, it may almost be said that it cannot be defined, because as applied to different classes of yarn it has altogether different meanings. Without attempting to give definitions, an effort will be made to show what the different qualities or characteristics of yarn comprise, and so ascertain what tests are necessary to decide their suitability for the purpose to which they are to be applied.

The first step in yarn testing is to test the counts, which means to find the weight and size of the yarn. As previously explained, there must be some standard measurement or weight, and some means of determining the bulk or quantity of yarn. In this case the determination is based upon the length of yarn in a given weight, as, for instance, the number of yards per pound, ounce, or grain; but in different yarns and different sections of the country, this is a variable quantity. For example, the counts of cotton are figured by hanks per lb., and the hank contains 840 yards. Worsted is also figured by the hank, but the length of yarn is 560 yards. The basis of linen calculations is the lea, which is practically equivalent to the hank, but contains 300 yards. Woolen is reckoned in a variety of ways, but chiefly by 1,600 yards to the pound.

There appears then to be only one way of dealing with this subject so as to meet the requirements of students of different dis-

tricts, and that is, to deal with it on general lines, and illustrate with examples from the best known and generally recognized system of counting yarns, and in such a manner that the student can readily adapt himself to any other system.

**Testing for Counts.** The process of testing for counts in the cotton and worsted systems, in which the method of indicating the count is general, may now be explained. In testing these yarns in the mill, there are two systems in use; one by what is known as the "quadrant", which is a balance with a graduated scale and upon which a certain number of yards is placed, when a pointer indicates the counts; the other system is by weighing with an ordinary fine balance and grain weights. The latter test is frequently done in a careless manner and very inferior balances employed, with the result that the tests are very unsatisfactory.

The "*quadrant*" arrangement is very useful because the indicator shows the counts the moment the yarn is put on the hook. The arrangement is very simple in principle, being in fact nothing more than an adjusted balance or lever. If it is arranged for cotton or worsted, the two arms of the lever, that is, the hook end and the indicator respectively are so balanced that one is, say, seven times the weight of the other, or more properly speaking that their relation to each other and to the scale is as 7 to 1. Then, if  $\frac{1}{7}$  of a hank is placed upon the hook, the indicator is at once brought to the point on the scale which shows the number of hanks per pound. When cotton is to be tested, 120 yards are measured off and placed upon the balance, and the pointer at once indicates the counts; if worsted, 80 yards are measured off and balanced with a similar result.

It must be clearly understood that the "quadrant" balance is always made for a given class of work, and to weigh a given number of yards; it is not usually made so that it can be applied to every purpose, but, like most special machines, must be applied to the testing of a specified class of yarn, and a specified number of yards weighed. Of course, the operator may vary this with a little ingenuity, but this would involve calculations, and consequently the machine would lose its advantages.

*Reeling.* By this system any length of yarn may be reeled off and weighed and the exact counts found by calculation.



This operation is carried on by means of a reel; one of the best examples of which is shown at Fig. 1. A sufficient length of yarn can be readily measured on this machine to test the counts to the greatest degree of accuracy.

The reel is 54 inches, or one and one-half yards, in circumference, and the dial is graduated into 120 parts to indicate the number of yards reeled from each spindle. While feeding yarn upon the reel, the yarn guides and the spindles are kept in line with each other, this being very desirable, in fact, necessary when reeling fine yarns. The extra length of the yarn guides is useful in increasing the friction upon the yarn by taking a half turn or more around them. The automatic feed motion lays the yarn flat upon the reel, thus securing accurate and uniform measurement, and consequently correct results as to stretch, strength, and numbering. When the skein is taken off the reel, it is weighed and the counts calculated from the weight.

It is a common practice to reel yarn upon a machine of very inferior construction, and in a very rough manner, which of course produces doubtful results. For example, in reeling worsted yarns, it is a common practice to use a reel with a circumference of one yard, and which does not distribute the yarn in the manner indicated. The number of yards which will correspond to the intended counts of the yarn is measured off by counting the turns of the reel, then this yarn is weighed in a common apothecaries' balance against a weight of  $12\frac{1}{2}$  grains, and if it balances or approximately balances the  $12\frac{1}{2}$  grains, it is said to be of the counts indicated by the number of yards weighed. Similar systems are sometimes used in the cotton and woolen industries, and, in some cases, the methods are, if possible, even more crude. But, although this is the common practice, it is not sufficient for good work, therefore, we must have more complete systems.

The first question which suggests itself is, how is the  $12\frac{1}{2}$  grains found to be the constant weight, and what weight would be employed for other yarns? The grain weight, being the lowest of the recognized standard weights, is made use of, and as there are 7,000 grains in one pound (Avoirdupois), this is divided by 560 (the number of yards in one hank) which gives  $12\frac{1}{2}$ . For cotton  $8\frac{1}{3}$  grains would be the constant; for woolen,  $4\frac{3}{8}$  grains.



*How to ascertain the number of cotton yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards of the yarn, observing that the greater the number the more accurate the result will be.

**Rule 27.** Multiply the number of yards by  $8\frac{1}{3}$  and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks in a pound.

Example. Suppose 9 yards weigh 5 grains; then  $9 \times 8\frac{1}{3} =$

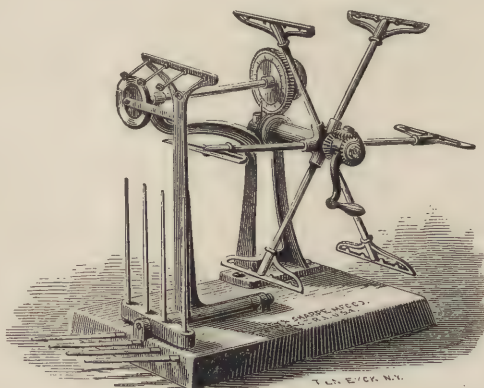


Fig. 1. Brown & Sharpe Yarn Reel.

75.  $75 \div 5 = 15$ 's. the number of yarn; *i.e.*, the number of hanks to a pound.

**Rule 28.** *To ascertain the number of linen yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be. Multiply the number of yards by  $23\frac{1}{3}$  and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn.

Examples. Suppose 12 yards weigh  $17\frac{1}{2}$  grains; then  $12 \times 23\frac{1}{3} = 280$ .  $280 \div 17\frac{1}{2} = 16$ , the number of counts per pound. Suppose 9 yards weigh 5 grains; then  $9 \times 23\frac{1}{3} = 210$ .  $210 \div 5 = 42$ , the count of the yarn.

**Rule 29.** *To find the number of worsted yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be.

Multiply the yards by  $12\frac{1}{2}$  and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks or skeins to the pound.

Example. Suppose 9 yards weigh 5 grains; then  $9 \times 12\frac{1}{2} = 112.5$ .  $112.5 \div 5 = 22\frac{1}{2}$ , the number of the yarn.

**Rule 30.** *To find the run or number of woollen yarn.* Reel, or measure off, and weigh any number of yards of the yarn, observing that the greater the number the more accurate the result will be. Multiply the number of yards by  $4\frac{3}{8}$  and divide the product



Fig. 2. Sample Scales.

by the weight of the sample in grains; the quotient will be the number of hanks per pound.

Examples. Suppose 90 yards weigh 45 grains; then  $90 \times 4\frac{3}{8} = 393.75$ .  $393.75 \div 45 = 8\frac{3}{4}$ , the number of run of the yarn. Suppose 9 yards weigh 5 grains; then  $9 \times 4.375 = 39.375$ .  $39.375 \div 5 = 7.875$  or  $7\frac{7}{8}$ , the number of the yarn.

The common practice in testing yarns is what might be termed a rough and ready one, yet it is often considered sufficient in ordinary practical work, but for good analysis a more perfect and delicate system must be used.

Suppose, for instance, that it is required to reproduce a cloth, or for any purpose to make a complete analysis of it. The operation ought to be conducted with as much care and nicety as a chemist makes a quantitative analysis; in fact, it must be a quantitative analysis. The counts of the yarn must be ascertained with

the greatest degree of exactitude, as well as the different quantities of the material employed, threads and picks per inch, etc., and if only a small piece of cloth is available, there must be careful work. Of course, by long experience and careful observation, a manufacturer may guess, or, as he terms it, "judge" with a degree of accuracy what the yarn is, but this is not accurate enough. He may have to try many experiments, some of them costly, before he arrives at the result desired, whereas a system of analysis, carefully carried out, will give him results at once. This applies at present to testing yarns for counts, and ascertaining the number of threads per inch in a sample, but it will apply to other systems which will come under notice in due time. Then as to the requisites for this work.

*Scales.* The first and most important is a good balance. Of these there are many styles which weigh to different degrees of accuracy. Small balances or scales may be had for a few dollars, and for a student who cannot give more for his own private use, they are better than nothing, certainly better than trying to guess the counts of yarn. A good balance, and one which may come within the students' reach is shown at Fig. 2. These balances are made to work with the utmost degree of accuracy, and will weigh one pound by ten thousandths of a pound.

The scales illustrated at Fig. 3 are still better, however, as they weigh by the grain system. These scales will weigh one pound by tenths of grains, or one seventy thousandth part of one pound Avoirdupois, which makes them especially well adapted for use in connection with yarn reels, for the numbering of yarn from weight of hank, giving the weight in tenths of grains to compare with tables.

These scales can be had to weigh by the metric system to  $\frac{1}{100}$  gram, being supplied with weights of 1, 2, 5, 10, 20, 40, 60, 100, and 200 grams.

When the testing is merely for percentages, the gram weights are the most convenient, as they are based upon the decimal system, but where it is a question of ascertaining the counts of yarn or the weight of cloth, the grain weights are the best to use. With the above series of scales and weights, tests can be carried out to almost perfect accuracy.



When a very small quantity of yarn is available, say one or two yards, it must be weighed with great care. Of course, when a large quantity is available, find now many yards will weigh  $12\frac{1}{2}$  grains, if the yarn is worsted;  $8\frac{1}{3}$  grains if cotton; and so on for other yarns, according to the system of counting. Suppose, for instance, that it is required to test the yarn in a cloth, and only a small piece can be obtained, say two or three square inches. This

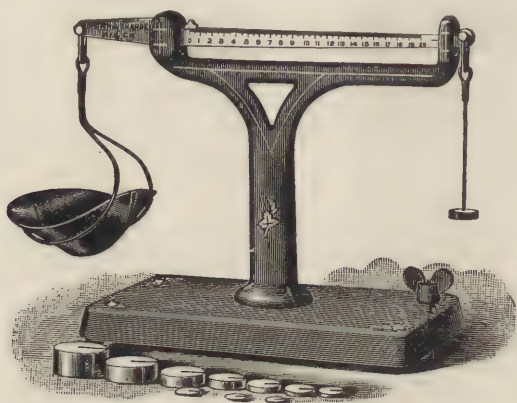


Fig. 3. Brown & Sharpe Scales.

must be measured carefully, and as many threads taken out as will make one yard, two yards, or as much as possible. For example, let it be two yards of worsted weighing  $1\frac{39}{100}$  grains. Find the counts. If two yards weigh  $1\frac{39}{100}$  grains, how many yards will weigh 7,000 grains? Putting it in the usual form of a proportion as  $1\frac{39}{100} : 7,000 :: 2 : 10,072$  yards, or there are that number of yards in one pound. As there are 560 yards per hank in worsted, and the counts are indicated by the number of hanks per pound, the 10,072 must be divided by 560, thus  $10,072 \div 560 = 18$  hanks nearly, then the counts would be called 18's, as it is near that number. If it were cotton, the same rule would apply, but instead of dividing by 560, the yards would have to be divided by 840 thus,  $10,072 \div 840 = 12$  hanks, or equal to 12's counts. If it were woolen on the run system, it would be divided by 1,600, and so on for other varieties of yarn. In such small quantities as this, there is always some slight liability to error, but with careful work this should not exceed 2 per cent.



The problem may be simplified by putting it in the form of an equation. Let  $Y$  represent the number of yards or length weighed, and  $W$  the weight in grains found. There are 7,000 grains in one pound and a fixed number of yards per hank in the system upon which the yarn is counted, then

$$\frac{7,000 \times Y}{560 \times W} = \text{counts in worsted,}$$

$$\frac{7,000 \times Y}{840 \times W} = \text{counts in cotton, etc.}$$

This may be further simplified as the 7,000 grains and the yards per hank are constant numbers. Let the grains be divided by the yards per hank and find one constant number, thus for worsted

$$\frac{7,000}{560} = 12\frac{1}{2} \text{ as the constant; for cotton}$$

$$\frac{7,000 \times Y}{840 \times W} = 8\frac{1}{3} \text{ for constant.}$$

Now let  $C$  represent the constant, and the formula will stand

$$\frac{C \times Y}{W} = \text{counts.}$$

#### TESTING BY COMPARISON.

As we have said that in some mills yarns are tested by comparison, this lesson would not be complete without giving an idea as to the method employed.

It consists in taking a few threads from the fabric, and these are crossed and folded over the same number of threads of some known count, the two ends of each respective group of threads being held between the fingers, the group of the unknown in one hand and the known in the other. The two groups are then twisted simultaneously so as to compare their relative diameters.

Fig. 4 illustrates this method of comparing known with unknown counts.  $A$  represents the known and  $B$  the unknown counts. Take one, two or more threads of each kind of yarn and placing them together, as shown in the illustration, twist them, making, as it were, one continuous thread: By this simple act of twisting it is natural to make a comparison of the area and solidity

of the threads. It is advisable to wet the yarns at the point where they are crossed, previous to twisting. During comparison, threads are added or taken from one or the other of the sets and again twisted as directed and compared until the two sets appear to make a similar thickness of thread.

It follows that when the number of threads of a known count are of equal thickness to some other number of threads of unknown counts, these numbers bear a simple and direct proportion to each other.



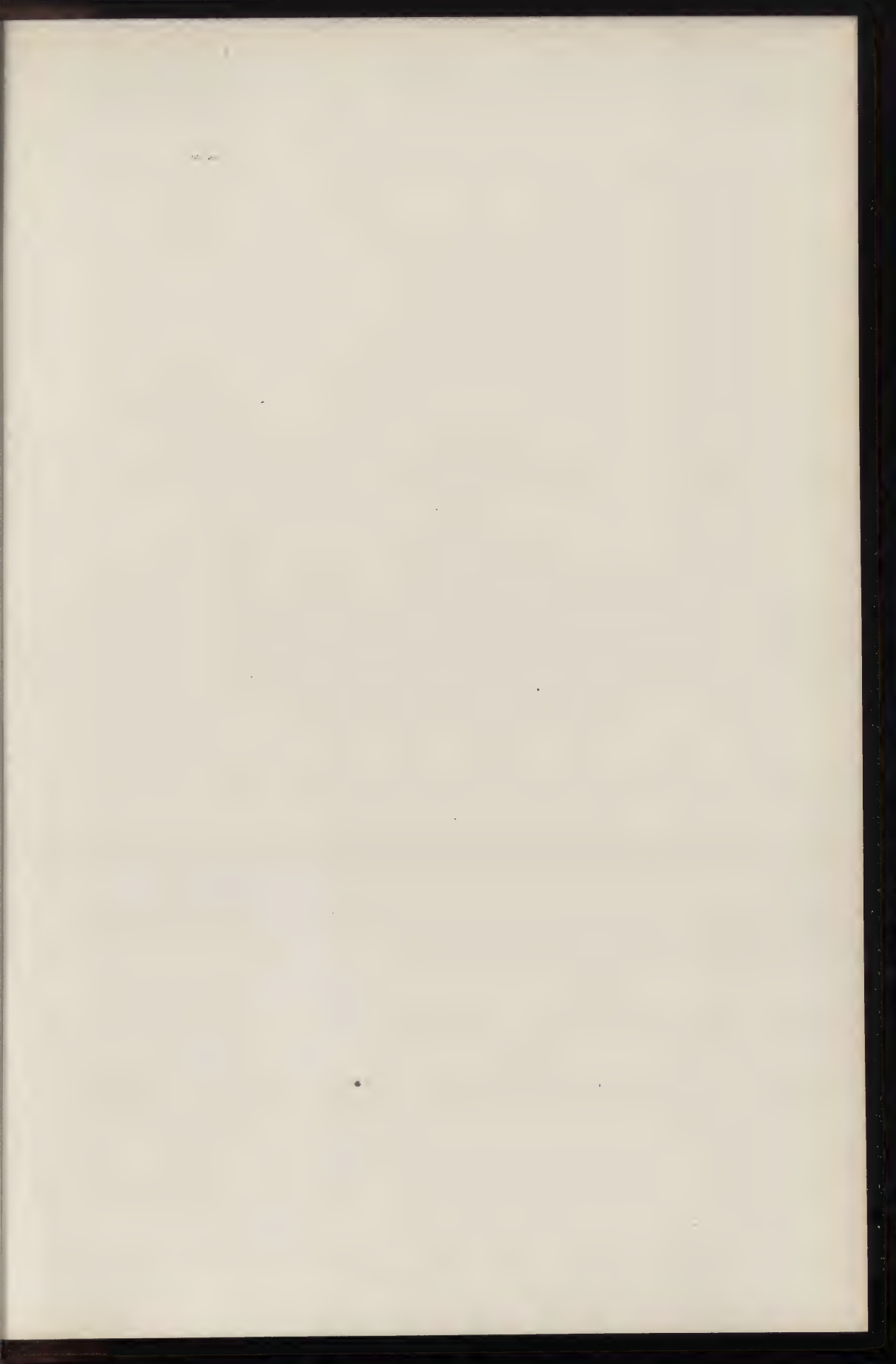
Fig. 4. Testing by Comparison.

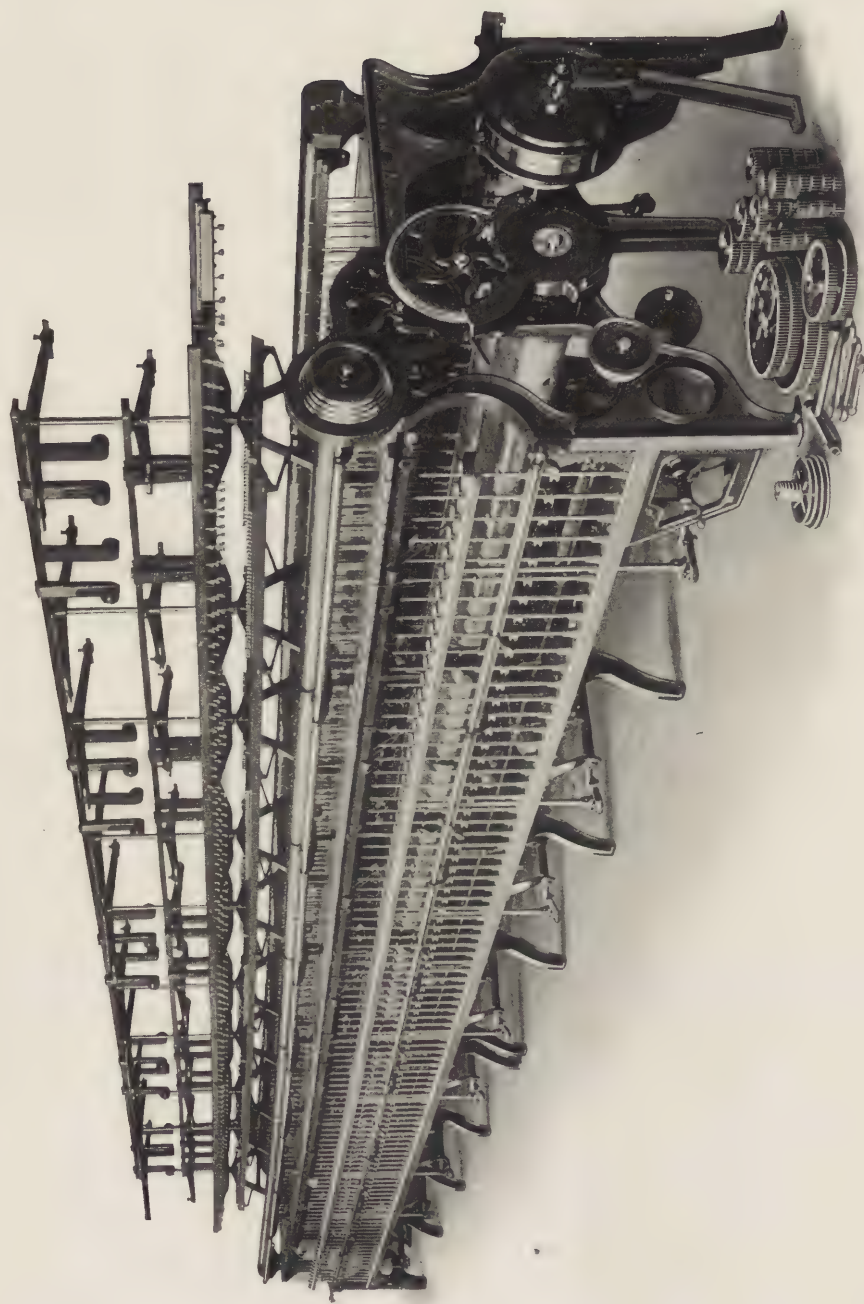
Example. 6 threads of 2-30's worsted are found by twisting and comparison to equal 8 threads of some unknown count. What is the count of the unknown threads?  $2-30's = 15$ . Then as  $6 : 8 :: 15 : \times = 20's$ , or 2-40's worsted *i.e.*, 8 threads twisted together of 2-40's are equal in thickness to 6 threads 2-30's worsted twisted together.

This method of testing is used practically, because a mill-man usually uses the nearest counts he has in stock to the counts of yarn in the sample to duplicate. Others do not trust to the eye when comparing yarns, but prefer to use a magnifying glass or microscope.

#### Constants for Testing Yarns for Counts by Weighing Short Lengths of Cotton.

1. 1,000 divided by weight in grains of 1 lea = counts.
2. The number of inches that weigh 1 grain  $\times .2314 =$  counts.
3. Number of yards weighed  $\div .12 \times$  weight in grains = counts
4. The number of strands of yarn, each  $4\frac{5}{16}$  inches or 4.32 inches long that weigh 1 grain = counts.
5. The number of yards weighed  $\times 8\frac{1}{3} \div$  weight in grains = counts.





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## STRUCTURE OF CLOTH.

Structure of cloth does not mean the fabric, nor the yarns from which the fabric is constructed, but it designates the materials from which the fabric is made, together with the system of interweaving. It has been explained that no woven fabric can be produced without crossing, or interweaving at right angles, two distinct sets of threads. In the Instruction Papers on Textile Design several systems of interweaving are given and the meaning of plain or cotton weave, prunella twill, cassimere twill, basket or hopsack weave, five-harness sateen, etc., are explained. Now, the object is to find the *quantity and kind of yarn*, which, when used with certain weaves will produce a fabric of good structure.

The *plain weave* is the simplest texture, requiring only two threads of warp and two picks of filling to complete the full weave. Not only is it the simplest, but it is the most limited in size. If two threads are drawn in on the same harness side by side, or two picks are placed in the same opening or shed, it is not a plain weave, and if one thread is taken away, the fabric is left without any means of binding or interweaving.

Adding to the plain structure and only admitting of one additional thread and pick, we enter on the first lesson of figure and twill weaving, and the weave is designated as the *three-harness twill or prunella twill*. This is the first form of diagonal or rib effect at an angle of 45 degrees, and with the variations of this weave we can work out designs on a figured basis by twilling to the right for a number of threads and then reversing the twill, using either the warp-flush or the filling-flush weaves or combining the two.

The addition of one more thread forms the *swansdown weave*, which is a regular four-harness filling-flush twill, advancing one thread and one pick in regular consecutive order, forming a twill or diagonal at an angle of 45 degrees. We may say that with this number of threads, or this weave, the field for new combinations is unlimited, for with four harnesses, an endless variety of fabrics are constructed, such as dress goods, men's wear, etc. Weaves which repeat on four harnesses are very useful in cotton, woolen, and worsted manufacture.

Adding one more thread and one more pick gives five threads

in the warp, and five picks in the filling; the smallest number on which a *sateen weave* may be constructed. There is in use a weave of four harnesses called the crowfoot weave, which is sometimes called a sateen or doeskin, but as the first and second threads run consecutively to the right, and the third and fourth run consecutively to the left, it cannot be a sateen. A true sateen must in no instance have two threads running consecutively either to the left or to the right.

Sateens generally have a warp-flush surface, which gives a soft and full appearance to the fabric and are used more or less in the construction of fancy figured goods and piece-dyed fabrics, such as damasks and table linen, covert coatings, beavers, etc. As the weave is either a warp-flush or a filling-flush face, the character of the cloth is always of a limited nature.

*The derivatives of the sateen* are very diversified in character, but more perfect in structure than those obtained from other weaves or modes of interweaving.

So far, we have been considering simple weaves or cloths constructed on a one-weave basis, but the method of constructing fabrics from a combination of several weaves, is a most comprehensive one and the effects produced cover a wide range of fabrics.

**Combination of Weaves.** In all cases when a fancy figured effect is required in cloth made from the same shade of yarn, this principle is invariably adopted, as every plan of interweaving, whether twill, basket, diamond, herring-bone, spotted or all-over effects, can be produced by a combination of weaves.

The essential points to be noticed in combining or amalgamating two, three, or more weaves are (*a*) class of fabrics to be constructed, (*b*) the capabilities of each weave intended to be combined with other weaves.

Some weaves are specially adapted for cotton effects, others for silk, woolen, or worsted. To combine weaves without due consideration as to their utility is a useless toil. To amalgamate weaves for fulled-woolen goods is a waste of time, as weaves for woolen goods should be of a regular and uniform character, and those nearly approaching each other are preferable. In cotton and worsted goods the opposite characteristics are desired, and the man-

ner of interlacing is of the utmost importance; the principal feature of a worsted fabric being its decided and clearly defined weaves.

Our considerations have thus far been the structure of a fabric as affected by the weave. For our next consideration we will take the structure of a fabric as affected by its relation to warp and filling.

The *strength*, *utility*, and the *purpose of the structure* must be considered. Generally speaking, the smaller the yarns, the larger the flushes in weaves which may be employed. A cloth constructed with yarn 2,560 yards to the pound, 24 threads to the inch using the plain weave would be firm and regular in construction, but if it were woven in an 8-harness twill, 4 up and 4 down, it would be very loose, coarse and open in construction. This clearly shows that weaves that are useful for one class of yarn, are not suitable for all, so we must have in mind the quality of texture required, when laying out or constructing a cloth.

When combining weaves the importance of the filling capacity must not be lost sight of, and when several weaves are combined, the complete design must possess a similar capacity for the admission of the filling.

The construction of a cloth in its broadest sense is, to consider the weave, size of yarns and materials of which they are made, and also to enter into the details and calculations required in connection with the correct method of building a perfect structure. *The following points should be noted when constructing a fabric:*

Weave, or combination of weaves.

Judgment in selecting weaves for combination.

The class of fabric intended to be produced, whether wool, worsted, cotton, or silk.

The weaving capabilities of the separate weaves to be combined.

Weaves combined to have an equal filling capacity.

The purpose and utility of the fabric.

Nature of the raw material to be used.

The size of the yarns for warp and filling.

The number of turns of twist to be put in warp and filling yarns.

The number of threads in the warp per inch.

The number of picks of filling per inch.

The take-up in weaving.

The process in dry finishing.



Scouring, fulling, shearing.  
Finishing shrinkage.

#### DIAMETER OF THREADS.

The square root of the yards per lb. will give the diameter of the yarn, or the number of threads which will lie side by side in one inch without being interlaced with another set of threads.

Example. Suppose a cloth is to be made from 80's cotton, and it is desired to ascertain the number of threads that will lie side by side in one inch of space.

$80 \times 840 = 67,200$  yards of 80's cotton in 1 lb. Extracting the square root of 67,200

$$\sqrt{67,200} = 259.22.$$

Allow 7 per cent for shrinkage of yarn from first spin.

$$259.22 - 7\% = 241.07.$$

NOTE.—When the tension, which is put on yarn in spinning, is removed, cotton shrinks 7 per cent; worsted 10 per cent; woollen 14 per cent; and silk 4 per cent.

As a fraction, it will give the diameter of the thread, as  $\frac{1}{241}$  of an inch, therefore, 241 threads of 80's cotton would lie side by side in one-inch space. The same rule will apply to woollen and worsted yarns, where the basis of the calculations is of a similar character.

Example. Suppose a cloth is wanted from 40's worsted.

$$40 \times 560 = 22,400 \text{ yards per lb.}$$

$$\sqrt{22,400} = 149.66 - 10\% = 134.70 \text{ (approximately 135.)}$$

Therefore 135 threads of 40's worsted will lie side by side in 1 inch.

**Rule 31.** To find the diameter of any yarn use the square root of 1 counts in yarn required, as a constant number, and multiply the square root of the counts of the required diameter by the constant. Thus the square root of 1's worsted is  $\sqrt{560} = 23.66$ .

$$23.66 - 10\% = 21.30$$

What is the diameter of 16's worsted yarn?

$$\sqrt{16} = 4. \quad 21.30 \times 4 = 85.20.$$

Proof.  $560 \times 16 = 8,960. \quad \sqrt{8,960} = 94.65 - 10\% = 85.19.$



**BALANCE OF CLOTH.**

There are no definite rules to determine what is perfection in a textile fabric. The term "Balance of Cloth" is capable of wide interpretation, but the generally accepted meaning is the proportion in which the warp and filling stand to each other. A second interpretation is the distance the threads are set from each other according to their weight and diameter. This would be correct if all cloths were made on the same principles, but as all classes of fabrics are not made for the same purpose, either as to wear or general utility, no definite nor systematic rules can be given that will apply to every variety of textiles.

Suppose a concern is making dress goods, and has found that the layout or construction of this fabric, on a plain weave basis, is all that can be desired. The warp and the filling threads are made of the same material, and the warp is so set in the reed that the *diameter of the threads* and the *spaces between the threads* are equal; the filling threads are equal in counts or diameter to the warp threads, and there are the same number of threads and spaces in the same area as there are in the warp. This layout may be considered as representing an equally balanced fabric, and it does not matter what the material may be, whether cotton, linen, woolen, or silk, the construction of such a cloth is perfect and is made on the truest principles.

Taking the plain cloth as here laid out as the foundation for a reliable basis, we have something on which to commence our further studies on cloth construction.

It very frequently happens that to produce special effects, this principle must be departed from. We may wish to make a cord or rib running in the direction of the warp, or we may wish the cord to run across the cloth in the direction of the filling. These two fabrics are made on two distinct principles, and although the variation in texture is due to alterations and modifications in the weave, the foundation of both is the plain weave. In the plain weave the threads are equal, both warp and filling being deflected; but in a corded effect, one set of threads is heavier than the other, which results in the light thread being bent and the heavy thread retaining its straightness.

In such instances, there is no space between the warp threads

for they may be in *actual contact*, and the number of threads per inch determined by the diameter of the threads, without any allowance for space between them. Poplins are a good illustration of this construction. In this class of goods the cords run across the cloth, and instead of the warp threads having a space between them equal to the diameter of the threads, they must be set very closely together, and the filling threads some distance apart, otherwise the clear cord will not be produced. Care must also be taken that the filling threads are not too far apart, or the corded effect will be destroyed. When producing a cord parallel to the length of the cloth the procedure is exactly the reverse.

From these two examples we come to another conclusion, *i.e.*, on the warp cord, the warp is present in larger quantities than the filling, while on the filling cord, the filling is the larger quantity. It has been stated that as the warp or filling preponderates, it must be *increased in quantity*, and that which is least seen must be *decreased*. This rule holds good for nearly all makes of cloth.

**Twilled Cloths** differ very much from plain fabrics. By the construction of the weave the threads must be closer together, for the same counts of warp and filling, to produce a cloth of equal firmness. A plain cloth is interwoven at every thread and pick whereas in a twill cloth, the picks pass over a number of threads before they are interwoven, therefore, weaves which produce long floats require heavier yarn or a closer set to produce an approximate firmness of texture. The number of threads and picks per inch must be increased in proportion to the length of the floats.

In twilled cloths, the warp or filling may be made to preponderate on the face of the fabric in two ways, (*a*) as in plain cloth by having more threads of one set than of the other, at the same time decreasing the diameter of one set of threads, and increasing the diameter of the other, or (*b*) by weaving the desired set of threads on the face.

**To Change From One Weave to Another and Retain the Same Perfection of Structure.** As has been explained in regard to the plain fabric, when it was desired to change from the plain weave to a fancy twill or diagonal, it may occur that one of these fancy twills may be desired in some other effect, and at the same time be necessary that no alteration of the structure of the fabric take place.

A heavier or bolder twill may be desired, or it may be that the twill is too deep or prominent, or that a still lighter fabric is in demand. The layout or texture of the original fabric is known and it is required to construct a new fabric of exactly the same character, and also to use the same size and quality of yarns as in the first cloth, thus saving the expense of making new yarns. For example, we have a cloth woven with the 4-harness cassimere twill, 80 threads per inch, warp and filling being equal. We now desire the same build of cloth, made from a design that will give a bolder twill, so the 6-harness common twill  $\frac{3}{3}$  is used. How many threads and picks per inch must be used in the new fabric?

- (a) Obtain the number of threads and units in known weave.
- (b) Obtain the number of threads and units in required weave.
- (c) Obtain the number of threads and picks per inch in known fabric. (Threads and picks per inch is known as texture.)

**Rule 32.** Multiply the number of known threads or texture by the units of the known weave, and by the threads of the required weave, and divide the product by threads of known weave, multiplied by the units of required weave.

The term unit is given to the threads and intersections of a weave. For example, the plain weave has one thread up one thread down, expressed  $\frac{x}{x}$ . Each pick of filling passes over threads 1, 3, 5, 7, etc., and under threads 2, 4, 6, 8, etc., or *vice versa*, thus forming a space between every thread and those on either side. To find the number of units, the weave should be expressed  $\frac{x}{x}$  the crosses representing threads, and the vertical lines representing intersections. It will be seen that the plain weave contains two threads and two intersections, or four units.

The cassimere twill would be two threads up and two threads down, expressed  $\frac{xx}{xx}$  which shows four threads and two intersections, or six units.

The three up and three down twill would be  $\frac{xxx}{xxx}$  or six threads and two intersections, or eight units.

Proceeding with the problem given above

$$\frac{\text{Texture (80)} \times \text{known weave units (6)} \times \text{threads of required weave (6)}}{\text{Threads of known weave (4)} \times \text{required weave units (8)}} = 90$$



Thus 90 threads and picks per inch on a 6-harness twill will give the same texture as 80 threads and picks per inch on a cassimere twill with the same counts of yarn.

It is required to change from the weave, 2 up, 1 down, 1 up, 2 down; to the weave 2 up, 1 down, 1 up, 1 down, 1 up, 4 down. The texture is 72 threads and 72 picks per inch.

First weave has 6 threads and 4 intersections = 10 units.

Second weave has 10 threads and 6 intersections = 16 units.

$$\frac{72 \times 10 \times 10}{6 \times 16} = 75 \text{ threads and picks per inch.}$$

If it is necessary to make the cloth lighter and maintain the structure of the heavier cloth, and to use the same yarn, a firmer weave must be used to reduce the number of threads per inch. Proceed in the following manner:

- (a) Obtain the number of threads and units in known weave.
- (b) Obtain the number of threads and units in the required weave.
- (c) Obtain the texture of known weave by finding threads and picks per inch.

**Rule 33.** Multiply the known texture by the threads of the required weave and by the units of the known weave, and divide the product by the units of the required weave multiplied by the threads of known weave.

If a fabric woven with the weave 3 up, 1 down, 1 up, 3 down, 3 up, 1 down, 1 up, 3 down, has 80 threads per inch, and we wish to use the weave 2 up, 1 down, 1 up, 2 down, 2 up, 1 down, 1 up, 2 down; how many threads will be required to maintain the exact structure of the original cloth?

First weave has 16 threads and 8 intersections = 24 units.

Second weave has 12 threads and 8 intersections = 20 units.

$$\frac{\text{Texture (80)} \times \text{threads required weave (12)} \times \text{units of known weave (24)}}{\text{Units of required weave (20)} \times \text{threads of known weave (16.)}} = 72$$

Thus 72 threads per inch will give the same texture on the second weave that is produced by 80 threads per inch on the first weave; using same counts of yarn.

In all these examples it is assumed that the warp and filling are equal in size, quality, and texture of the fabric, and the fabric



is built on the principle of what is generally understood as a square cloth.

Having determined that a truly balanced cloth is where the number of threads and picks are equal and of the same diameter, and having determined what sett of reed will give the best result for a given number of yarn, it is easy to find what sett will suit any other count of yarn to produce a similar result. For example, we will take four threads of a plain cloth.

$$\begin{array}{rcl}
 \begin{array}{|c|c|c|c|} \hline x & & x & \\ \hline & x & & x \\ \hline \end{array} & \begin{array}{l} 4 \text{ threads} \\ 4 \text{ intersections} \end{array} & \begin{array}{l} = 4 \text{ units.} \\ = 4 \text{ units.} \\ \hline 8 \text{ units.} \end{array}
 \end{array}$$

In a fixed rule, we assume that the proportions of size of yarn warp and filling, and spaces are equal, therefore we will take the diameter or size of yarn as the unit of measurement. Supposing our sample of plain cloth to have 60 threads per inch, and we wish to change the weave to the 4-harness cassimere twill.

$$\begin{array}{rcl}
 \begin{array}{|c|c|c|c|} \hline xx & & & \\ \hline & xx & & \\ \hline \end{array} & \begin{array}{l} 4 \text{ threads} \\ 2 \text{ intersections} \end{array} & \begin{array}{l} = 4 \text{ units.} \\ = 2 \text{ units.} \\ \hline 6 \text{ units.} \end{array}
 \end{array}$$

Four threads of plain cloth equal 8 units, while the same number of threads of the cassimere twill equals 6 units, therefore the twill weave will require a greater number of threads to make as perfect a fabric as the plain weave, and the increase is in proportion as 6 is to 8. Our example supposed the plain cloth to have 60 threads per inch, then to have an equal fabric with the twill weave, the problem will be  $6 : 8 :: 60 : X$  or 80 threads per inch.

As the cloth is built square, what has been said of the warp applies equally to the filling. The 4-harness cassimere twill interweaves regularly, the twill moving from end to end consecutively. Warp and filling flushes are equal, as in the plain weave, and the quantities of warp and filling on the face are equal.

Take another example—5-harness twill, 3 up and 2 down.

$$\begin{array}{rcl}
 \begin{array}{|c|c|c|c|c|c|} \hline xxx & & & & & \\ \hline & & xx & & & \\ \hline \end{array} & \begin{array}{l} 5 \text{ threads} \\ 2 \text{ intersections} \end{array} & \begin{array}{l} = 5 \text{ units.} \\ = 2 \text{ units.} \\ \hline 7 \text{ units.} \end{array}
 \end{array}$$

Two repeats of the weave would equal 14 units. Ten threads

of the plain weave would equal 20 units, therefore the 5-harness twill requires a *greater number of threads*.

The increase is in proportion as  $14 : 20 :: 60 : \times$  or  $85 \frac{71}{100}$ .

We will take a final example on the 6-harness common twill basis, three threads up and three threads down, the filling passing over and under three threads alternately, therefore there will be only 2 intersections;  $xxx | ooo | = 6$  threads and 2 intersections equals 8 units. In a plain weave, there would be 6 threads and 6 intersections, equaling 12 units, so this weave would require an *increase* as  $8 : 12 :: 60 : \times$  which equals 90 threads.

It must be thoroughly understood that the examples given herewith are all supposed to be made from the same material, same kind of yarn in weight and diameter, and the structure of the fabrics is exactly the same as far as the build is concerned, but as the 4, 5, and 6-harness weaves require more threads per inch to form as perfect a structure as the plain weave, the fabric when woven must necessarily be heavier. This is one of the important considerations when laying out a new fabric. The weight per yard has to be taken into account, therefore the size of yarn and weave are two very important factors.

In order to make proper use of previous calculations, and to put them into practice, it is necessary that the actual size of threads should be known, that is, the size, counts, and diameter to produce a perfect structure. Threads composed of different substances vary greatly in proportion to their weight. The specific gravity of cotton and linen is about  $1\frac{1}{2}$  times the weight of water. Animal fibers, silk and wool, have a specific gravity of  $1 \frac{3.0}{10.0}$  or nearly  $1\frac{1}{3}$ .

The *diameters* of linen threads are similar to cotton. Woolen yarns present a thicker thread for the same weight. Spun silk has about the same diameter as cotton.

We must now consider the diameter of yarns. Threads vary as to the square root of their counts. After finding the diameter of a thread, find how many threads will lie side by side in one inch. For any counts of yarn, find the number of yards per pound and extract the square root. The square root of number 1 cotton would be  $\sqrt{840} = 28.98$ . This is without any allowance for shrink, age, and without any allowance for space.

**Rule 34.** To change a plain weave into a fancy twill or diagonal and retain the same perfection of structure:

- (a) Obtain the number of threads in required weave.
- (b) Obtain the number of intersections in required weave.
- (c) Add threads and intersections together and call them units.
- (d) Obtain the units there would be in the number of threads of the plain weave that are occupied by the required weave.

Example. If a plain fabric has 80 threads per inch, what number of threads will it require for the weave 3 up, 3 down, 2 up, 1 down?

Multiply the units of the known weave by the threads per inch, and divide by the units of the required weave.

Explanation. In two patterns of the above weave, there would be 18 threads and 8 intersections = 26 units, a plain weave on 18 threads would have 18 intersections = 36 units.

$$26 : 36 :: 80 : \times = 110 \frac{77}{100}$$

Thus 110 threads will be required to produce a fabric on the required weave, which is equal in texture to 80 threads on a plain weave; the same yarn being used in each case.

### DISSECTING AND ANALYZING.

In the manufacture of textile fabrics, there are at least two important divisions of a designer's work: (a) *designing*, (b) *dissecting and analyzing*.

**Designing** consists in the building of a fabric from designs, more or less original, and the weaves, texture of the fabric, and colors used in its manufacture are limited only by the looms and yarns under the designer's control.

**Dissecting and Analyzing** differs widely from designing and is the most important work in a design office. In this case the designer must reproduce or imitate a fabric; which is a difficult problem if not worked in the right way. A thorough knowledge of designing in all its branches, and a theory of the many calculations necessary, together with the most expedient manner in which the theory may be put into practical use are essential for a successful analysis.

Many designers perform their work without any special meth-

od, which causes great inconvenience to themselves, and results in a useless waste of time and material. A methodical designer can perform his work in a comparatively short time with far better results, saving the manufacturer considerable time and expense. The first principle of a designer should be *method*, for method leads to economy, which is one of the foundations of a mill-man's success. Too much stress cannot be laid upon this point, and if the beginner is methodical and continues so, dissecting and analyzing will prove comparatively easy to him.

When analyzing a fabric, many important facts must be considered, especially when it is desired to reproduce the fabric. The nature of the fiber from which the yarn is spun, the quality and twist of the yarn, colors, and weaves used to produce the desired effect, and the character of the finishing processes should all be carefully studied, in order that the reproduction may be perfect in every detail.

The first thing to determine is the *class and nature of the fabric*. Double, triple, and backed cloths may be easily determined by a close inspection of the sample, one side usually being woven with coarser yarn than the other. Heavily napped fabrics should first be singed, care being taken to singe the nap without injuring the yarn in any way; while single cloths need but a glance to classify them as such.

The next step is to decide upon the face and the back of the fabric. Double and triple cloths usually are woven with a heavier yarn on the *back* to add weight and strength to the material. This is especially true of the so-called "two and one" system. Frequently "one and one" cloths are woven with yarn of equal counts, and the face is determined only by one or more of the several tests described later. The conditions which apply to double cloths also apply to backed cloths.

Worsted dress goods and similar fabrics often prove confusing, but in many cases a close examination will show that one side is smoother to the touch than the other, and the "draw" is very noticeable. By passing the fingers one way of the cloth a smooth feeling is noticeable and this is termed the "draw". Passing the fingers the other way of the cloth a slight resistance is felt, which is termed the "bite". These conditions are caused by shearing,



and are undoubtedly the best test for the determination of face and back. Union goods are usually woven with the animal fibres more prominent on the *face*.

The next thing to consider is the scheme of warp and filling, and the texture of the fabric, and is practically the first step in dissecting.

Every woven fabric is composed of two sets of threads or yarns. Those running lengthwise in the fabric or in the direction of the warp are commonly termed threads, while those running across the fabric, or in the direction of the filling or weft, are termed the picks. From now on, the terms threads and picks will be used to denote warp and filling respectively.

We are now confronted by the problem of determining which is warp and which is filling. If the sample contains a portion of the selvage there is no difficulty, for the selvage always runs in the direction of the warp. If, however, the sample is cut so that no portion of the selvage is present the warp may be determined by any of the following tests:

(a) If the yarn is double and twisted one way and single the other, the double and twisted yarn will indicate the warp.

(b) If the yarn is harder twisted one way than the other, the yarn with the harder twist is the warp.

(c) If one set of yarn is finer than the other, it is safe to say that the finer yarn forms the warp. Usually yarn used for warp is finer than that used for filling.

(d) If the yarn one way appears straight and regular, and the other way loose, rough, and displaced, or not strictly regular, the straight yarn is assumed to be the warp.

(e) Reed marks of any kind will show which is the warp.

(f) If the yarn one way is single or double cotton, and the other way is single woolen, the cotton is invariably the warp.

(g) If the yarn one way is starched or sized, and the other is not, the starched yarn is the warp. Warps are sized or starched to add strength or weight to the yarn.

(h) The test for nap has been previously stated and is valuable to denote the warp, for the nap lies in the direction of the warp.

(i) Stripes are generally formed by the warp.

(j) A fabric may be woven with the yarn right twist one way

and yarn left twist the other way. The former is invariably the warp.

Exceptions to these tests seldom occur. In many fabrics, varying conditions prevail, but the reasons for such variations are so pronounced, especially with yarn, that little examination is required to distinguish the warp from the filling.

Warp yarn is usually stronger and finer than filling yarn, with a harder twist, and made from the best and strongest material on hand.

**Texture.** The density of a fabric is controlled by the texture, and its required weight and thickness. The sample should be cut to a certain size, usually 1 inch square, and each thread drawn out of the fabric separately and laid aside in its proper order. Each thread should be examined in turn, and the *twist*, *nature*, and *color* determined as it is drawn out of the sample. This will save a repetition of the work later on. When only a small sample is available the texture and color scheme must necessarily be determined at the same time.

Having drawn out each set of yarn, warp, and filling, the texture may be ascertained by counting the number of threads in each lot. If in the sample on hand there are 56 threads in the warp and 48 threads in the filling, the texture will be 56 threads and 48 picks per inch. It is not always convenient to cut the sample 1 inch square, and the threads and picks per inch may be determined by accurately measuring the length and width of the sample, and dividing the picks and threads respectively by these measurements. A sample may be  $\frac{3}{4}$ -inch long and  $1\frac{1}{2}$  inches wide and contain 36 and 84 threads respectively. The calculations would be

$$36 \div \frac{3}{4} = 48 \text{ picks per inch.}$$

$$84 \div 1\frac{1}{2} = 56 \text{ threads per inch.}$$

NOTE.—This is not a reliable method and, if possible, should be avoided.

As the threads are drawn out, care should be taken to find the number of each variety and color of yarn, and in their exact order. When a repeat has been found by adding the number of threads of each color and variety, the threads in a pattern are determined. Suppose the threads in a sample are as follows:

Twist cotton	2	2	= 4
White worsted		2	= 2
Green worsted		2	= 2
			<u>8</u>

Thus there are 8 threads in a pattern, 4 twist cotton, 2 white worsted, 2 green worsted.

Fabrics, such as plaids, frequently have a fancy arrangement of warp and filling, and the threads in a pattern exceed in number the threads and picks per inch. Determine the extent of the repeat in the sample and measure it accurately. By dividing the number of threads in a pattern by the number of inches the pattern occupies, the texture may be found. Thus, a pattern  $2\frac{1}{2}$  inches wide contains

Red cotton	18		= 18
Blue cotton	36		= 36
Yellow cotton	4		= 4
Dark tan		54	= 54
White		48	= 48
Light tan		80	= 80
			<u>240</u>

$$240 \div 2.5 = 96 \text{ threads per inch.}$$

The easiest way to ascertain the woven construction of a fabric, is to take it from the face or from the figure presented on the surface of the fabric; but this requires experience and familiarity with the many kinds of weaves. Constant practice in constructing cloths from designs, and noticing the woven effects of each particular "*sign*", "*riser*", or "*sinker*" used on the point or design paper is the best way to become familiar with weaves. But sometimes, the sinkers and risers are so intermingled, several individualities being contorted and merged into one eccentric combination, that even experts find it necessary to resort to unravelling or "*picking-out*" each warp and filling thread, in order to find the true character of the weave.

The picking out of samples presents no difficulties except those of concentrated sight and steady application. This only refers, however, to fast-woven and much felted cloths, in which all the crossings have become nearly, if not totally, obliterated. If the texture were as open as mosquito netting, there would be no



difficulty, because every crossing of the threads, warp, and filling could be distinctly seen and marked.

Of course there are gradations from the most openly constructed to the finest setted fabrics, and from the least to the most heavily felted cloths; still the principle of dissection is the same in all.

There are other particulars to be obtained from a sample, besides the weave or figure, and upon which the figure depends for its appearance. These are the relative fineness of the warp and filling, and the number of threads per inch, and also the amount and kind of finish to be given to the fabric to gain solidity and handle, as well as effect. We say nothing here of the materials of which the threads are composed.

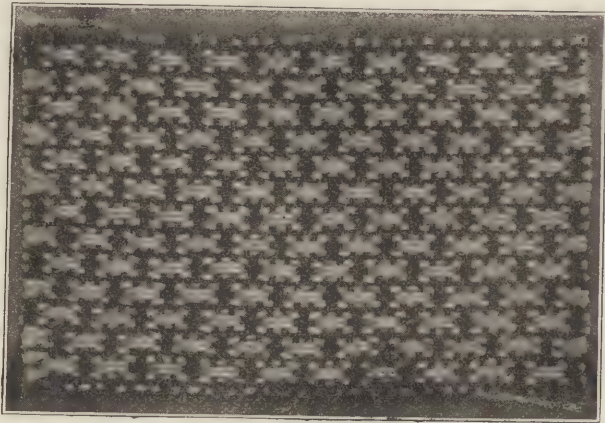


Fig. 5.

Now, suppose a sample of finished cloth exactly 1 inch square is to be analyzed. The first procedure is to weigh it in very fine (grain) scales, and record the weight. Assuming that the weight of one square inch is 5 grains and that the finished cloth is 56 inches wide, we proceed to find the weight of one yard of cloth.

**Rule 35.** To find the weight of 1 yard of cloth, weight of 1 square inch and width being known. Multiply the grains per inch by the given width of cloth  $\times 36$ , and divide by 437.5 grains. The answer will be weight in ounces per yard.

$$\frac{5 \times 56 \times 36}{437.5} = 23.04 \text{ ozs. per yard.}$$



Or the constant found by dividing 437.5 by 36 may be used as follows:

$$5 \times 56 \div 12.153 = 23.04 \text{ ozs. per yard.}$$

NOTE.—The weight of woven fabrics is usually expressed in ounces, and as there are 7,000 grains in one pound Avoirdupois,  $7,000 \div 16 = 437.5$  grains per ounce.

**Rule 36.** To find the weight of one yard of cloth when the weight of any number of square inches is known; weight in grains of sample  $\times$  width  $\times$  length, divided by square inches  $\times$  437.5 grains.

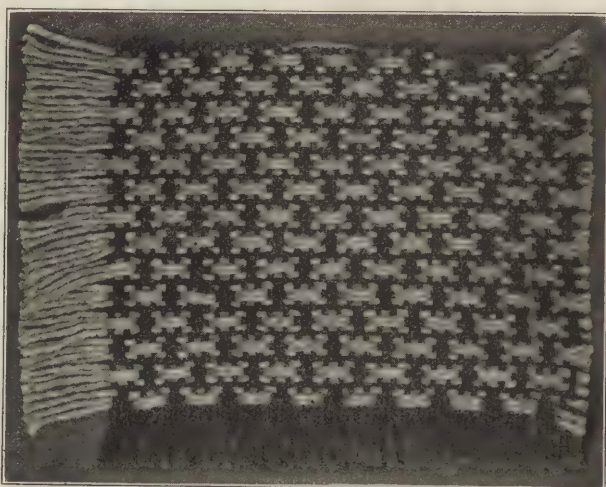


Fig. 6.

Assuming that a sample which contains 4 square inches weighs 20 grains and the cloth is 56 inches wide the process would be as follows:

$$\frac{20 \times 56 \times 36}{4 \times 437.5} = 25.04 \text{ ounces per yard.}$$

The above explains the general principles which underlie the method of obtaining the weight per yard of any fabric, woolen, worsted, cotton, linen, or silk, of any given width, and should be thoroughly understood by all who are employed in the designing room, weave rooms, or in the superintendent's or manager's office.

This simple formula with explanations will apply to all fabrics.

$$\frac{\text{Grains} \times \text{width} \times 36''}{\text{sq. inches} \times 437.5} = \text{ounces per yard.}$$

## PICKING-OUT.

(a) Trim the edges of the sample perfectly square with the warp and filling threads. (See Fig. 5.)

(b) Unravel, by taking out about one-quarter of an inch of warp threads from the left side of the sample and about one-quarter of an inch of filling threads from the bottom part of the sample. (See Figs. 6 and 7.)

(c) Take the sample in the left hand between the finger and the thumb, placing the warp threads in a vertical position, that is, the first thread of weave on the left and first pick of weave nearest your body.

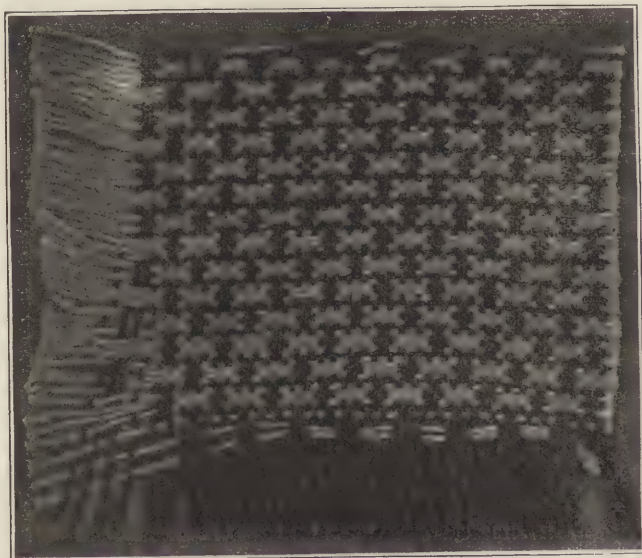


Fig. 7.

A piece of design paper must be at hand to mark down the result of the pick-out, as shown in the diagrams. With a small pointed instrument, say a needle, commence at the *left hand bottom corner* and lift the first thread away from the body of the cloth so that the filling crossing can be seen.

Now notice which filling threads this first thread is over and under, and mark on the design paper (commencing at the left hand bottom corner) those picks which are down; the up picks, of course, will be represented by the blanks or vacant squares. For instance,

the first warp thread is over the first and second picks, under the third pick, over the fourth pick, under the fifth pick and sixth pick, over the seventh pick, and under the eighth pick: that is, over two, under one, over one, under two, over one and under one. The ninth and tenth are like the first and second, the eleventh is

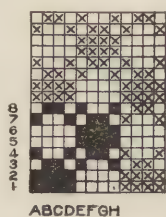


Fig. 8.

like the third and so on; so the first eight picks represent one repeat of the weave on the first thread, and is represented on the design paper by the black filled-in squares on thread A, Fig. 8.

Now remove the first thread, lift the second thread to the front, and proceed as before. The second thread is over the first 3 picks under 4, over 4 and so on as shown at the thread marked B. Each succeeding thread is treated in the same manner until the weave or design repeats.

When the pattern is found to be repeating in either direction, the pick-out need not be continued, yet for safety it is advisable to go far enough both ways and then fill in the design at the repeats and disregard the other crosses. This design is complete on 8 threads and 8 picks, as shown at Fig. 9.

Fig. 9 also shows the drawing-in draft\* and harness chain. The design is reduced to four harnesses to work it easily. The letters above the drawing-in draft correspond with those in Fig. 8 and denote the order of the threads and the order of their drawing-in upon the harness, and the figures under the draft the number of the harness upon which each thread must be drawn, according to the design, while those on the left hand side show the number of harnesses employed. The numbers on the left of the reduced chain show the condensation of the design and draft. Fig. 10 shows the interweaving of the threads.

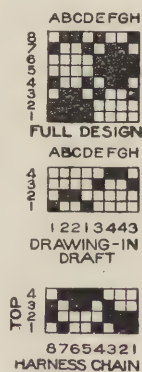


Fig. 9.

However intricate the sample or design may be in its woven construction, this method will simplify it. Sometimes the design will not repeat on so small a number as  $8 \times 8$ ; and if the sample is not large enough to obtain one-half repeat, a larger sample must be obtained if possible, unless it is seen that the design runs in



regular order, when a few threads taken out are sufficient to show the principle of construction without going further.

With constant practice in the analysis or picking-out of samples, the character of the figure or weave may be ascertained almost as well as in its production in the loom, as in both cases one becomes familiar with signs, sinkers, and risers and their effects.

The preceding remarks have had reference to comparatively easy and simple textures for analysis, such as worsted or cotton

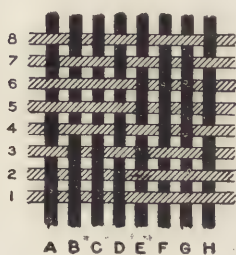


Fig. 10.

goods, but with the more heavily felted woolen fabrics a little preparation is necessary before proceeding with the above method. Any fibers which obstruct the clearness of the design and prevent the interweaving of the threads from being clearly seen must be removed by singeing or shaving the surface; care being taken that the threads are not destroyed, or damaged so that they cannot be removed, or followed in their regular course.

**Pattern.** Having found the construction of the weave, so far as figure or design is concerned, the next procedure is to note the number of threads which complete the pattern in each direction.

Referring to Fig. 11, the analysis of which is given on the analysis sheet, it will be noticed that the scheme or pattern of warp is, 2 threads of light, 1 thread of dark, 2 threads of light and 2 threads of dark, or

$$\begin{array}{rcl} \text{Light} & 2 & 2 & = & 4 \\ \text{Dark} & & 1 & 3 & = & 3 \end{array}$$

7 threads in pattern, or scheme of warp.

The pattern or scheme of the filling is 3 picks of dark and 2 picks of light, or

$$\begin{array}{rcl} \text{Dark} & 3 & = & 3 \\ \text{Light} & 2 & = & 2 \end{array}$$

5 picks in pattern, or scheme of filling.

Referring again to the analysis sheet for data the analysis is as follows:

1. Weight of 1 yard, given width.

**NOTE.**—Pattern refers to color only, design or figure refers to weave. In the first example the warp is dark and the filling light, which is termed solid colors. Pattern is the arrangement of colors as they lie side by side in the warp and filling.



SAMPLE CLOTH ANALYSIS.

The analysis or dissection of a sample of cloth consists in obtaining the following particulars:

Fabric.....	Worsted Dress Goods.....	(See Fig. 11).....
Data.....	One square inch.....	weighs.....1.7 grains.....
Threads per inch (finished cloth).....	56.....	weigh.....9 grains.....
Picks per inch (finished cloth).....	50.....	weigh.....8 grains.....
Width within selvages (finished).....	36 inches.....	
Remarks.....	56 threads per inch equal 56 inches of worsted yarn.....	
	50 picks per inch equal 50 inches of worsted yarn.....	
1. Weight of one yard inside selvages....	$(1.7 \times 36 \times 36) \div 47.5 = 5.07$ ozs. per yd.	
2. Pick-out.....	See Fig. 12.....	
3. Drawing-in draft and chain.....	See Fig. 12.....	
4. System or dressing of warp.....		
.....Light.....	2    2    = 4.....	
.....Dark.....	1    2    = $\frac{3}{7}$ .....	
5. System or scheme of filling.....		
.....Dark.....	3    = 3.....	
.....Light.....	2    = $\frac{2}{3}$ .....	
6. Threads in warp.....	$36'' \times 56 = 2016$ ends.....	
7. Threads in warp pattern.....	7.....	
8. Patterns in warp,.....	$2016 \div 7 = 288$ .....	
10. Size (counts or run) of warp in finished cloth.....		
.....	$(56 \times 7000) \div (.9 \times 560 \times 36) = 21.6$ worsted counts.....	
11. Size (counts or run) of filling in finished cloth.....		
.....	$(50 \times 7000) \div (.8 \times 560 \times 36) = 21.7$ worsted counts.....	
Note. These counts represent the yarn just as it lies in the sample.....		
It is not stretched.....		
11. Weight of warp yarn in one yard of finished cloth.....		
.....Light.....	$288 \times 4 = 1152$ .....	
.....Dark.....	$288 \times 3 = 864$ ..... $(2016 \times 16) \div (21.6 \times 560) = 2.66$ ozs..... 2016	
12. Weight of filling yarn in one yard of finished cloth.....		
.....	$36 \times 50 = 1800$ ..... $(1800 \times 16) \div (21.7 \times 560) = 2.37$ ozs.....	
.....	$2.66 + 2.37 = 5.03$ ozs. per yard.....	

$$\frac{\text{Grains} \times \text{width} \times 36}{437.5} = 5.03 \text{ ozs. weight per yard.}$$

2 and 3. Pick-out, drawing-in draft and chain (see Fig. 12.)

4. System or pattern of warp according as the colors lie side by side in the fabric. (See Page 56.)

5. System or pattern of filling, according as the colors lie side by side in the fabric. (See Page 56.)

6. Threads in warp. Width (36)  $\times$  threads per inch (56) = 2,016.

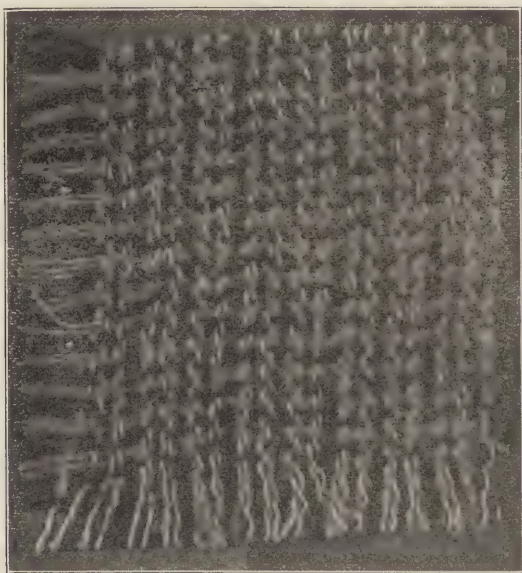


Fig. 11.

7. See No. 4 for warp and No. 5 for filling.

8. Patterns in warp. Threads in warp (2,016)  $\div$  threads in pattern (7) = patterns (288).

9. Size (counts or run) of warp in finished cloth 21.6.

NOTE.—See rules for the various ways of obtaining counts from small quantities or short lengths of yarn.

10. Size (counts or run) of filling in finished cloth 21.7.

11. Weight of warp yarn in one yard of finished cloth. Width of goods (36") multiplied by threads of warp per inch (56) gives the total number of yards of warp yarn in one yard of goods, or

2,016 yards. As the warp yarn is numbered 21.6, or as it takes 21.6 times 560 yards to equal 1 pound of yarn, the weight of above 2,016 yards would be  $\frac{2,016}{21.6 \times 560} = \text{lbs.}$ , or multiplied by 16 = 2.66 oz. of warp yarn in one yard of cloth.

12. Weight of filling yarn in one yard of cloth. The picks of filling per inch (50) times width of cloth (36) gives the length in inches of filling in one running inch of the cloth or 1,800 inches. Multiplying this amount by 36 inches gives the number of inches of filling in one running yard of cloth. Again dividing by 36 inches, reduces it to yards.

$$\frac{1,800 \times 36}{36} = 1,800 \text{ running yards of filling in one yard of cloth.}$$

NOTE.—As multiplying and dividing by 36 would be superfluous, it is omitted from the formula.

Following our reasoning in the explanation given in a previous



Fig. 12.

paragraph, counts of filling  $\times 560$  yards gives the number of yards in 1 pound of filling, therefore,

$$\frac{1,800}{21.7 \times 560} = \text{lbs.}, \text{ or multiplied by } 16 = 2.37 \text{ ounces, filling yarn in one yard of cloth.}$$

$$\text{Weight of warp yarn in one yard} = 2.66$$

$$\text{Weight of filling yarn in one yard} = 2.37$$

$$\text{Weight of yarn in one yard} = 5.03 \text{ ozs.}$$

*The weight of yarn in one yard should equal the weight of finished cloth per yard.*

**Take-up.** So far the analysis has been simply as the yarn stood in the cloth. Yarn in a finished piece of cloth must have more or less crimps or corrugations in it according to the weave or design used.

The plain weave which interlaces at every thread and pick will require a longer warp than the 4-harness swansdown weave, to produce a fabric of equal length, provided all other things are equal.

This is a very important point in the analysis of any fabric. It must be remembered that a *yard of yarn will not weave a yard of cloth*, so cloth is always shorter than the original length of warp from which it was woven, which is due to the take-up by its being bent around the filling.

The *cloth is always narrower than the width the warp was spread in the reed* previous to being woven, which is due to the filling pulling in the edges of the cloth and to the filling bending around the warp threads. It is a well-known fact, that cloth from two looms working side by side may vary in width and length, and each loom working apparently under same conditions.

The material of which yarn is made and the manner in which it is spun, dressed, and manipulated in the loom, has much to do with the take-up in the weaving and finishing processes. The finer the quality of the filling and the softer it is spun, as compared with the warp, the greater take-up there will be in the width. Increased tension on the warp increases the length of the cloth, and makes the width narrower, up to a certain limit. If the filling is hard twisted and of a coarse nature, or coarser than the warp, the cloth will not take up much in the width.

The warp for plain stripes and sateen stripes should not be placed on the same beam nor reeded in the same manner, as the plain weave will take up much faster than the sateen portion. Care should be taken in reeding weaves of variable intersections.

The difference in temperature, weather, system of sizing, kind of loom used, tension of warp, tension of filling, also number of reed and picks per inch as compared with each other will affect the amount of take-up.

The yarns in weaves of the rib and cord type, where three, four, or more threads or picks work together, act like heavy yarns and tend to retain a straight line, the finer yarns bending around them, consequently the fine yarns have the greater take-up.

Rules may be given which will give good results and which have been proved to be practical, to some extent, for finding the various items necessary for the reproduction of a fabric, yet they are only approximately so, the best results being obtained by experience and using the records of other fabrics.

NOTE.—Take-up will be further explained under the heading "Take-up and Shrinkage".



## SETTS AND REEDS.

Having found the weave, draft, chain and counts of yarn as they appear in the finished fabric, the next important step is to find the "sett" in loom, which includes reed, dents per inch, threads per dent, approximate counts of the warp and filling yarns previous to being woven, and finally the picks per inch in loom.

The density of the warp threads in the process of weaving and subsequently in the woven fabric, is represented by the relative number of heddles on the harness shafts, and the dents in the reed distributed over a fixed unit of space, which will include the number of warp threads passed through each dent in the reed.

The system of numbering reeds now almost universal in all the textile industries (perhaps with the exception of silk) is known as the "*threads per inch*" system. The number of dents per inch in the reed with two threads in each dent is the basis of the sett. If the reed has 40 dents per inch it is called a 40's reed or 80's sett.

$$40 \text{ reed} \times 2 \text{ threads} = 80 \text{ threads per inch.}$$

Obviously, the "dents per inch" is the simplest basis for a sett system and should be adopted where English measurements are used.

For all reed calculations in this work, one inch is given as the unit of measurement, and the number of warp threads contained in that space, forms the basis of the sett. When the threads per inch are of an equal number, the reed for the divisions is easily found, that is for ordinary requirements. For instance, if 40 threads per inch are required, a 20's reed 2, 10's reed 4, or 8's reed 5 may be employed; that is, a reed having 20 dents, 10 dents, or 5 dents per inch, each dent containing 2, 4, or 5 threads respectively.

By this method the number of threads for the whole warp is easily ascertained as follows: A warp is required to be 70 inches wide, with 40 threads per inch, then  $70 \times 40 = 2,800$  threads are required for the warp.

A cloth has to be woven in a 100's sett, 4 threads in each dent. How many dents per inch must the reed contain?

$$\text{Sett} \div \text{threads in dent} = \text{Reed.}$$

$$100 \div 4 = 25$$

A cotton fabric is woven 3 threads in a dent, 42 inches wide, and

warp contains 2,520 threads. What is the sett and what is the reed?

$$\text{Warp threads (2,520)} \div \text{width (42)} = \text{sett (60)}$$

$$\text{Sett (60)} \div \text{threads (3)} = \text{reed (20)}$$

A reed contains 1,320 dents in 33 inches, 2 threads in each dent. What is the reed?

$$\frac{\text{Dents (1,320)}}{\text{Inches (33)} \times \text{Threads (2)}} = 20 \text{ reed.}$$

Given 120 threads per inch, to be laid 72 inches wide in loom. How many threads in warp? Threads per inch (120)  $\times$  width (72) = threads in warp (8,640).

**Unevenly Reeded Fabrics.** The requirements of design and the construction of the cloth are so various as to sizes of yarn, and the number of threads per inch employed in the warp, that the number of dents per inch in the reed is dependent upon it. But the number of threads in each division of the reed is not always uniform, that is, not always the same number in each dent throughout the whole width of the warp, this depending upon the pattern to be woven. For example, in the production of a fancy sateen stripe while 2 threads in each dent may be required, say for  $\frac{3}{4}$ -inch space, the following dents may require 3, 4, 5, or 6 threads in them, and then repeat with 2's and so on through the width of the reed. This will show that no hard and fast rule can be laid down which will cover every requirement.

**Example.** A worsted stripe is made in which the warp contains 1,920 threads; it is laid 40 inches wide in the reed, and reeded as given below. Find the average number of threads per inch, and the number of reed.

Pattern 1 dent = 4 threads black.	$1,920 \div 24 = 80$ patterns.
1 " = 4 " white.	$80 \times 6 = 480$ dents.
1 " = 6 " black.	$480 \div 40 = 12$ reed.
1 " = 4 " white.	$1,920 \div 40 = 48$ average.
1 " = 4 " black.	$48 \div 12 = 4$ average
1 " = 2 " white.	in each dent.
6 dents 24 " in pattern.	

**Rule 37.** To find average threads per dent, and reed for cloth, number of threads per dent varying. First find the number of threads in one pattern and the number of dents which they occupy,

then divide the total number of threads in the warp (1,920) by the number of threads in the pattern (24) which gives the number of patterns in the warp (80), this multiplied by the dents in a pattern (6) gives the total number of dents required to reed the warp (inside selvages). The number of dents (480) divided by the width of the cloth (40) gives the number of reed (12). Dividing the threads in the warp (1,920) by the width of the cloth (40) gives the average threads per inch (48), and dividing this by the reed (12) gives the average threads in each dent. Dividing the number of threads in a pattern (24) by the dents in a pattern (6) will also give the average number of threads in each dent.

A fabric is made with 3,264 threads in the warp; set 40 inches wide in the reed, and is reeded as given below. Find the number of dents per inch in the reed.

30 threads	2	in a dent	=	15 dents
20 "	1	" " "	=	20 "
12 "	2	" " "	=	6 "
Miss one dent	0	" " "	=	1 "
12 threads	2	" " "	=	6 "
Miss one dent	0	" " "	=	1 "
12 threads	2	" " "	=	6 "
20 "	1	" " "	=	20 "
30 "	2	" " "	=	15 "
<hr/>				
136 threads in 1 pattern.				90 dents in 1 pattern.
3,264 ÷ 136 =				24 patterns.
24 × 90 =				2,160 dents.
2,160 ÷ 40 =				54 reed.

A cotton sateen stripe fabric has 3,520 threads in the warp and is reeded in a 40's reed as given below. What is the width in reed?

22 threads	white	}	2 in dent.
6 "	lt. blue		
6 "	" pink		
6 "	" blue		
12 "	white	}	6 in dent.
12 "	lt. blue		
12 "	" straw		
12 "	" blue		
12 "	white		

4	"	pink	}	2 in dent.
4	"	blue		
4	"	pink		
4	"	blue		
4	"	pink		
12	"	white	}	6 in dent.
12	"	lt. blue		
12	"	" straw		
12	"	" blue		
12	"	white		
6	"	lt. blue	}	2 in dent.
6	"	" pink		
6	"	" blue		
22	"	white		

**TAKE-UP AND SHRINKAGE.**

**Cotton Cloth.** In cotton cloth, the take-up depends chiefly upon the character of the weave, and quality and counts of yarn used. The term "sley" is used to denote the number of threads per inch in the cloth.

Suppose we have analyzed a cotton sample, and there are 100 threads per inch, or 100 sley. Find the number of dents per inch in the reed to give this texture, using 2 threads in 1 dent.

Deduct 1 from the given sley and divide by 2.1.

$$100 - 1 = 99. \quad 99 \div 2.1 = 47.14 \text{ reed.}$$

As an illustration of how cotton cloths will vary in the amount of take-up according to the construction in weaving, the following examples are given:

1. A fabric made with 48's warp and 2-15's filling, 34 inches in reed, 88 threads per inch, 50 picks per inch, 5 harness sateen weave, gives  $33\frac{1}{2}$  inches of cloth. Showing a take-up of about  $1\frac{1}{2}$  per cent.  $34 - 33.5 = .5$ .  $.5 \div 33.5 = .0148$  or 1.48%.

2. 48's warp and 15's filling. 33 inches in loom, 64 threads by 40 picks. 5-harness  $\frac{4}{1}$  weave, gives 32 inches of cloth, showing a take-up of  $3\frac{1}{8}$  per cent or  $33 - 32 = 1$ .  $1 \div 32 = .03125$  or  $3\frac{1}{8}$  per cent.

3. 2-26's warp and 48's filling.  $31\frac{1}{8}$  inches in loom. 48 threads by 128 picks. 6-harness broken twill, filling face, gives



28 inches of cloth. Showing a take-up of 11.16 per cent.  $31\frac{1}{8} - 28 = 3\frac{1}{8}$ .  $3\frac{1}{8} \div 28 = .1116$  or 11.16 per cent.

These examples could be multiplied, showing the various take-ups by using weaves of various intersections and yarns of different counts, also by varying the number of threads per inch.

The following rules are on a basis of 5 per cent, and are given as approximately correct.

**Rule 38.** For cotton cloth. To find the number of dents per inch in reed to produce a given "sley".

Deduct 1 from the given sley and divide by one of the following numbers:

For 1 thread in dent divide by 1.05	
" 2 threads" " " " 2.1	
" 3 " " " " 3.15	
" 4 " " " " 4.2	

**Rule 39.** To find sley of cloth woven with a reed, the number of dents per inch being given.

Multiply the number of dents per inch by one of the following numbers and add 1:

For 1 thread in dent multiply by 1.05	
" 2 " " " " 2.10	
" 3 " " " " 3.15	
" 4 " " " " 4.2	

Examples. Find the number of dents per inch in reed, to give a 120 sley drawing 4 threads in each dent.  $120 - 1 = 119$ .  $119 \div 4.2 = 28\frac{1}{3}$  dents per inch.

What sley cloth would be woven with a reed containing 50 dents per inch, with 3 threads in each dent?  $50 \text{ dents} \times 3.15 = 157.5$ .  $157.5 + 1 = 158.5$  sley cloth, or threads per inch.

**Rule 40.** To find sley reed to produce unequally reeded patterns such as lenos, cords, dimities, etc. Multiply the threads in the pattern by patterns per inch, which will give the average sley: then multiply the average sley by the number of dents per pattern and by 2, and divide by the number of threads per pattern.

In a sample of cloth, the pattern is found to be reeded 2, 4, 4, 4, and there are 9 patterns per inch. What reed will produce it?

$2 + 4 + 4 + 4 = 14$  threads in pattern.  $14 \times 9 = 126$  average sley.

$$\frac{126 \times 4 \times 2}{14} = 72 \text{ sley reed.}$$

$$72 \div 2 = 36 \text{ actual reed.}$$

When figuring cotton fabrics, allowances must be made for quantity of size, starch, and other substances used.

**Worsted Cloth.** In the analysis and construction of worsted fabrics, that is, those composed of worsted warp and worsted filling, the same principles are to be observed as in cotton cloths.

Piece dyed worsted goods sometimes gain as much in weight in the dyeing operation as they lose in the process of scouring, so the weight of the cloth from the loom may be taken as net, and the calculations based accordingly.

The width of the warp in the reed depends upon the class of goods to be made, the required width of the finished piece, and the structure of the design. In ordinary worsted textures, the shrinkage of the cloth from the loom to the finished state, varies from 8 to 12 per cent.

A sample of finished cloth contains 80 threads and 80 picks per inch. Allow 10 per cent for shrinkage in the width and length. Find the width of the warp in the reed, and the number of threads and picks per inch with which it must be woven. The cloth is 56 inches wide finished.

$100\% - 10\% = 90\% \frac{80 \times 90}{100} = 72 \text{ threads and picks per inch in loom.}$

$\frac{\text{Threads (80)} \times \text{width (56)}}{\text{threads per inch (72)}} = \frac{\text{threads in loom (4,480)}}{72} = 62\frac{2}{3} \text{ inches.}$

The original length and width represented 100%. The shrinkage was 10%, so the finished cloth is 90% of the original length and width. As there are 80 threads and picks per inch in the finished cloth, there must have been a smaller number per inch when the length and the width were greater. Therefore, multiply the number of threads and picks by the finished width and length and divide the product by the original length and width.

To find the width in reed: First find the number of ends in the warp by multiplying the finished width by number of threads per inch in the finished cloth; then divide the product by the threads per inch in the loom.

Example. A worsted cloth contains 64 warp and filling threads. Shrinkage 9%. Finished width 55 inches. Find the reed width, and the number of threads and picks with which it should be woven.

Fancy worsted cloths are made from yarns dyed in the hank, or from yarns where the material has been dyed in the raw state or in the worsted top, therefore, the loss in scouring and finishing must be considered.

**Fulled Woolen Goods.** Fabrics which come under this head may have a finishing shrinkage of 20% to 35%, and in some cases even more. Such goods are said to be "made" in finishing, for the cloth as produced by the loom would not be recognized in the finished condition.

When analyzing a small sample of woolen goods, it is very important that the shrinkage be accurately found, or the reproduction will not be a success.

Method of finding picks in loom.

$$\frac{\text{Picks in finished cloth} \times \text{finished length}}{\text{length out of loom}} = \text{picks in loom.}$$

A finished woolen coating has 71 picks per inch. 63 yards of cloth out of loom gives 57 yards finished.

$$\frac{71 \times 57}{63} = 64 \text{ picks in loom.}$$

Or, a finished woolen suiting has 80 picks per inch, and it has had a shrinkage in length in the warp, or number of picks, of 20%. What was the number of picks in the loom?

$$100 - 20 = 80\%. \quad 80 \times 80\% = 64 \text{ picks in loom.}$$

There is a large number of fabrics for heavy clothing, that are made with a back stitched to the original or face fabric in order to gain weight and warmth. When analyzing such fabrics the counts and weight of the back cloth yarns are calculated as a separate cloth.

#### CONSTANTS.

Constants for the customary width of any fabric, whereby the weight per yard may be easily obtained from a small sample.

Formula.

$$\frac{\text{Width} \times \text{inches in 1 yard} \times \text{ounces in 1 lb.}}{\text{Grains in 1 lb. (Avoirdupois)}} = \text{constant.}$$

$$54 \times 36 \times 16 \div 7,000 = 4.44 \text{ constant.}$$

**Rule 41.** Weight of sample  $\times$  the constant  $\div$  sq. in. of sample = weight of yard, given width (54").

Sample.  $3 \times 2$  inches = 24 grains.

$$\frac{24 \times 4.44}{6} = 17 \text{ oz. per yard.}$$

#### TABLE OF CONSTANTS.

Inches wide.	Inches wide.
12 = .98	42 = 3.45
14 = 1.15	44 = 3.62
16 = 1.31	46 = 3.78
18 = 1.48	48 = 3.95
20 = 1.65	50 = 4.12
24 = 1.97	52 = 4.27
27 = 2.22	54 = 4.44
28 = 2.30	55 = 4.52
30 = 2.47	56 = 4.60
32 = 2.63	58 = 4.77
34 = 2.79	60 = 4.94
36 = 2.96	62 = 5.10
38 = 3.13	64 = 5.26
40 = 3.30	66 = 5.42

Example. A small sample 1 square inch = 5 grains. What is the weight of a yard of cloth 56 inches wide?

$$\text{Constant } 4.6 \times 5 = 23 \text{ ozs.}$$

The utility of this rule is at once apparent when applied to the solution of the above example, or to the following: A given sample is  $3 \times 3$  inches and weighs 27 grains. What is the weight if the fabric is 28 inches wide?

$$3 \times 3 = 9. \quad \frac{27 \times 2.3}{9} = 6.9 \text{ ozs.}$$

#### EXAMPLES FOR PRACTICE.

1. A sample is  $4 \times 1.5$  inches and weighs 18.5 grains. What will one yard of the fabric weigh, 54 inches wide?
2. What will one yard of cloth, 36 inches wide, weigh, if a small sample  $2\frac{1}{2} \times 2$  inches weighs 6.7 grains?
3. A yard of cloth 40 inches wide weighs 10.3 ozs. What will be the weight of a sample  $4 \times 2\frac{3}{4}$  inches?
4. What will one yard of cloth, 72 inches wide, weigh, if a  $4 \times 2\frac{1}{3}$ -inch sample weighs 30 grains?



## ANALYSIS OF PATTERN.

Cloths composed of one-color warp and one-color filling are said to be of solid color, but when there are two or more colors in the warp or in the filling, the arrangement of the colors is termed the pattern. Where several shades of colors of yarn are used in fancy fabrics, to produce certain effects, the order of the threads must be carefully noted to make a correct reproduction. Of course the order of arrangement of these threads may be ascertained during the process of dissection.

One thing to be attended to is, that the leading thread in the pattern should be found, with reference to the style of the design or weave employed. Sometimes particular threads are intended to show either prominently or the reverse and a special arrangement in the weave is made to produce this result. In such cases the *relation of the thread to its working arrangement* must be strictly observed, or the attempt at reproduction will be a failure. If the style of weave is all one kind, as in an ordinary twill or sateen weave, the above may be disregarded.

An additional consideration, with regard to these differently colored threads in the warp, and one which must receive attention is that, whatever number of threads there may be in the pattern, it must be repeated an even number of times in the width of the warp, so that if the edges of the cloth, minus the selvages, were brought together so as to form a tube, the pattern would be continuous all around.

Suppose that it is necessary to produce a fabric which contains 16 threads in one repeat of the pattern, as follows: 4 threads black, 2 threads drab, 2 threads slate, 4 threads black, 2 threads slate, 2 threads drab. This arrangement must be repeated as many times as is made necessary by the required width. A few extra threads may be disposed of by casting out, or a few may be added to make up even patterns.

Suppose a warp contains 1,920 threads and the pattern is composed of 16 threads.

Threads divided by number of threads in pattern equals number of patterns.  $1,920 \div 16 = 120$  patterns.

Suppose a warp fabric is measured and found to be  $32\frac{1}{4}$  inches wide and there are 48 threads per inch and 16 threads in the pattern.

$$48 \times 32\frac{1}{4} = 1,548 \text{ threads.}$$

$$1,548 \div 16 = 96 \text{ patterns} + 12 \text{ threads.}$$

*The 12 extra threads must be cast out.*

A fabric 35 inches wide contains 2,380 threads in the warp and is dressed 2 black, 2 white, 2 black, 1 red. (a) How many patterns are there in the warp? (b) How many threads per inch?

**Relative Weights of Warp and Filling.** There is yet another essential consideration in reference to these varied threads, for, in addition to finding the number of each kind, their weight also must be obtained, for the purpose of warping and dressing, as well as in making out the cost of the fabric. To the designer, spinner, and manufacturer calculations of this kind are very useful.

Find the weight of a warp 64 yards long, made of 2-32's worsted, and woven in a 16's reed, 4 threads in a dent, 66 inches wide in reed.

$$16 \times 4 = 64 \text{ threads per inch. } 2-32's = 16's.$$

$$\frac{64'' \times 66'' \times 64 \text{ (threads per inch)}}{16 \times 560} = 30.1 \text{ lbs.}$$

or

$$\frac{\begin{array}{cc} 4,224 & 64 \\ \text{threads in the warp} & \times \text{the length} \end{array}}{\begin{array}{cc} \text{counts} & \times \text{standard} \\ 16 & 560 \end{array}} = 30.1 \text{ lbs.}$$

Example. Find the weight of filling required to weave a piece 64 yards long, 64 inches wide in the reed, 80 picks per inch of 1-18's worsted. Add 5 per cent to cover the waste in weaving.

$$\frac{80 \times 64'' \times 64 \text{ (yds)} \times (100 + 5\%)}{18 \times 560 \times 100} = 34.1 \text{ lbs. of filling yarn.}$$

It must be remembered that a yard of warp will not weave a yard of cloth, and in making calculations, sometimes the length of the warp is taken instead of the loom length, the difference in length being considered sufficient to cover extra cost of waste of filling during the weaving.

#### EXAMPLES FOR PRACTICE.

1. Find the weight of warp and filling required to weave a piece 63 yards long, 64 inches in the reed, made from 70 yards of warp and containing 84 picks per inch, plus 5% for extra filling to cover the waste in weaving. Yarn is all 16's worsted.

2. A fabric 72 yards long is 56 inches wide in the reed, and contains 80 picks per inch. Waste in weaving 5%. 80 yards of warp are used in the fabric. Find the weight of warp and filling if both are 2-40's worsted.

3. 64 yards of warp are woven into a fabric 56 yards long. In the loom the cloth is 64 inches wide, and contains 50 picks per inch. 5% waste in weaving in filling. Find the weight of warp and filling if both are 14's cotton.

4. A woolen fabric is set 56 inches wide in the reed, and is woven with 40 picks per inch; 72 yards of warp finish to 64 yards of cloth. 5% waste in filling. What is the weight of warp and filling if both are 3-run woolen?

5. A 2-48's worsted warp 65 yards long is warped to the following pattern: Woven in a 12 reed, 4 threads in a dent, 60 inches wide.

$$\begin{array}{l} 2 \text{ black} \\ 2 \text{ dk. brown} \end{array} \left. \vphantom{\begin{array}{l} 2 \text{ black} \\ 2 \text{ dk. brown} \end{array}} \right\} \times 4$$

$$\begin{array}{l} 2 \text{ dk. brown} \\ 2 \text{ dk. drab} \end{array} \left. \vphantom{\begin{array}{l} 2 \text{ dk. brown} \\ 2 \text{ dk. drab} \end{array}} \right\} \times 2$$

24 threads in pattern.

$$12 \times 4 = 48. \quad 48 \times 60 = 2,880 \text{ ends in warp.}$$

$$2,880 \div 24 = 120 \text{ patterns.}$$

Find the weight of each color of yarn.

The following is the most convenient form to write out the scheme of warp and filling, as the summary of the threads can be obtained more easily. It is very essential to ascertain the weight, of each color and sort of material used, especially in the warp where the number of threads of each color and sort must be known, so that the several calculations can be made for spooling and warping.

Black	2	2	2	2		= 8 threads.
Dk. brown	2	2	2	4	2	= 12. "
Dk. drab					2 2	= 4 "
					24	" in pattern.

$$120 \text{ patterns} \times 8 \text{ threads} = 960 \text{ Black.}$$

$$120 \text{ " } \times 12 \text{ " } = 1,440 \text{ Dk. brown.}$$

$$120 \text{ " } \times 4 \text{ " } = 480 \text{ Dk. drab.}$$

$$\hline 2,880$$

The weight of each kind can now be obtained by the regular method.

$$\frac{960 \times 65}{24 \times 560} = 4.64 \text{ lbs.}$$

$$\frac{1,440 \times 65}{24 \times 560} = 6.96 \text{ lbs.}$$

$$\frac{480 \times 65}{24 \times 560} = 2.32 \text{ lbs.}$$

13.92 total weight of warp.

There is another method of obtaining the number of threads of each color.

Total number of warp threads  $\times$  threads of any color in one repeat  


---

 Number of threads in pattern.

$$\frac{2,880 \times 12}{24} = 1,440.$$

In patterns where there is a large number of threads of one color, as may be the case in a Scotch or Tartan plaid, it is advisable to commence the color scheme by *dividing the largest number of threads*, commencing with one-half and ending with the other.

A plaid is made from 2-24's worsted warp and filling, 12's reed, 4 in one dent, 44 picks per inch, width within selvages 36 inches, plus 24 threads on each side for selvages. The warp take-up is 15% during weaving, 60 yds. of warp before weaving. Selvages, white 2-24's worsted.

Black	24	6	20	20	6	24	= 100
White	12	6	68	6	12		= 104
Red		6			6		= 12
							216

This pattern has purposely been started with 24 threads of black (note the selvages are white), and finished with the same number and color. If the selvages had been ordered black, the pattern would have commenced with 34 white.

$$48 \times 36 = 1,728. \quad 1,728 \div 216 = 8 \text{ repeats.}$$

$$\text{Black} \quad 100 \times 8 = 800 \times 60 \div (12 \times 560) = 7.14 \text{ lbs.}$$

$$\text{White} \quad 104 \times 8 = 832 \times 60 \div (12 \times 560) = 7.43 \text{ lbs.}$$

$$\text{Red} \quad 12 \times 8 = 96 \times 60 \div (12 \times 560) = .86 \text{ lbs.}$$

1,728

15.43 lbs.

$$\text{Selvages white } 48 \times 60 \div (12 \times 560) = .43 \text{ lbs.}$$

15.86

NOTE.—The selvedge may be added to white in body of warp.



The weight of each color of filling is obtained by the use of a similar formula, but the width includes the selvages.

$$36 + 1 = 37'' \times 44 \text{ pks.} = 1,628.$$

$$1,628 \div 216 = 7.54.$$

$$\text{Black} \quad 7.54 \times 100 = 754$$

$$\text{White} \quad 7.54 \times 104 = 784$$

$$\text{Red} \quad 7.54 \times 12 = 90$$

$$\underline{1,628}$$

$$\frac{37 \times 44 \times 60}{12 \times 560} = 14.5 \text{ lbs., total weight of filling.}$$

$$\frac{14.5 \times 100}{216} = 6.72 \text{ lbs. of black filling.}$$

$$\frac{14.5 \times 104}{216} = 6.98 \text{ lbs. of white filling.}$$

$$\frac{14.5 \times 104}{216} = .80 \text{ lbs. of red filling.}$$

$$14.5 \text{ total weight of filling.}$$

The total weight can first be obtained, and then the proportions of weight of each color may be determined by the ratio of picks of each color to the total number of picks in each repeat, or multiply the number of picks per inch by 36, to find the number of picks in one yard, then multiply the result by the length of the warp, which will give the total number of picks in the whole piece. Divide the total number of picks by the number of picks in the pattern, to find the number of repeats. Multiply the repeats by the number of picks of each kind of filling, and again multiply these products by the width of the warp in the reed in the loom, which will give the total number of inches of filling of each kind. Divide the results by 36 to reduce to yards and by the counts of the yarn multiplied by the standard number to obtain the weight.

Lay a warp 72 inches wide in loom, 60 yards long, 4-run yarn. (40 picks per inch.)

Pattern of filling.	20 picks black
	1 " brown
	6 " black
	1 " brown
	20 " black
	<u>48</u>

There are 46 picks of black and 2 picks of brown in the pattern. Find the amount of yarn required of each color.

$$\begin{array}{r}
 36'' \\
 40 \text{ picks per inch} \\
 \hline
 1,440 \text{ " " yard} \\
 60 \\
 \hline
 86,400 \text{ picks in 60 yards} \\
 \hline
 \text{Total number of picks (86,400)} \\
 \text{Picks in pattern (48)} \quad ) = 1,800 \text{ repeats.} \\
 \hline
 \text{Brown} \quad \frac{1,800 \times 2 \times 72}{36} = 7,200 \text{ yards.} \\
 \hline
 \frac{7,200}{400} = 18 \text{ ounces.} \\
 \hline
 \text{Black} \quad \frac{1,800 \times 46 \times 72}{36} = 165,600 \text{ yards.} \\
 \hline
 \frac{165,600}{400} = 414 \text{ ounces.}
 \end{array}$$

The same rule applies to the picks of worsted and cotton by using their respective counts and standard numbers.

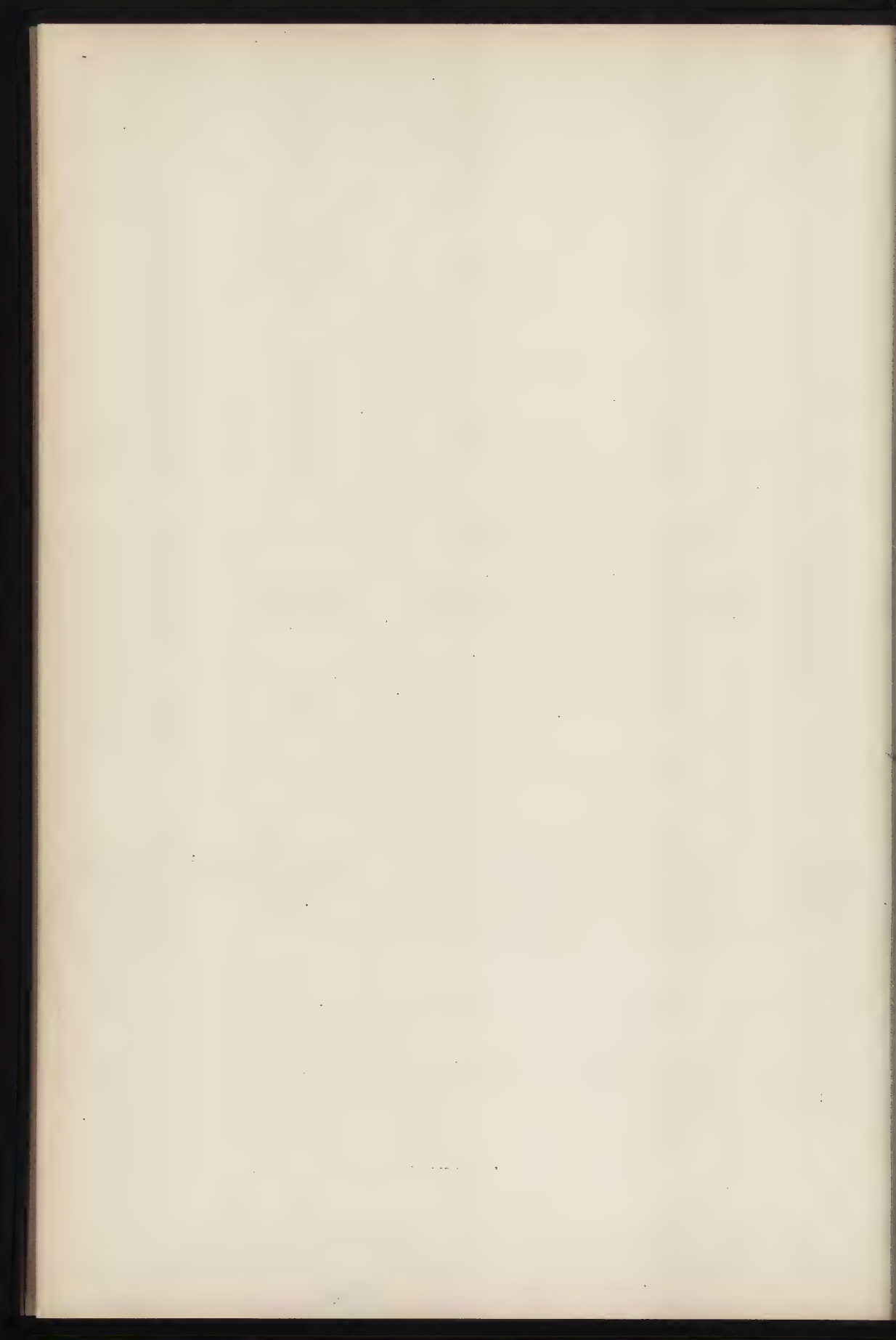
## REVIEW QUESTIONS.

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### PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for Civil Service Examinations. In some cases numerical answers are given as a further aid in this work.





## REVIEW QUESTIONS

ON THE SUBJECT OF

### TEXTILE CHEMISTRY AND DYEING

#### PART I

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1. Explain what is meant by hygroscopic moisture.
2. (a) In general, how do acids act towards cotton? (b) Give the special features in regard to the action of Sulphuric and Nitric acids on cotton. (c) What are Gun Cotton, Celluloid and Collodion?
3. What is chlorinated wool? What advantages may be derived by chlorinating wool?
4. (a) How is a silk fibre characterized? (b) Define "Scroop."
5. In general, how do acids act toward wool?
6. What are wild silks?
7. Of what value is cotton seed, and what is the process of separating the seed from the fibre called?
8. (a) In general, how do alkalies act toward cotton? (b) What special action does caustic soda have on cotton? (c) What practical applications are made of this action, and what general name is applied to the process?
9. (a) What are motes, dead cotton fibres, and kemps? (b) How do they act toward dyestuffs?
10. Compare the action of acids and alkalies upon cotton and wool, and give two methods of separating these fibres, based upon their difference.
11. What is the felting process and upon what principle does it depend?
12. In general, how do alkalies act toward wool?

## TEXTILE CHEMISTRY AND DYEING.

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13. Describe the common silk cocoon and the process of treatment previous to reeling.

14. (a) What is a conditioning establishment? (b) To what extent is silk hygroscopic?

15. What are the principal natural impurities of cotton?

16. Give the properties of artificial silk and describe its process of manufacture.

17. Describe the microscopic appearance of cotton.

18. Describe the structural and microscopic appearance of wool.

19. Describe the microscopic appearance of linen.

20. In general, how do solutions of metallic salts and dyestuffs act toward cotton?

21. (a) Describe the microscopic appearance of silk. (b) How does it differ in this respect from wool and the vegetable fibres?

22. (a) What is the approximate composition of raw cotton? (b) Give name, properties and composition of the principal constituent.

23. What can you say about the action of cotton towards atmospheric changes?

24. (a) What is Ramie Fibre? (b) Make a list of all the vegetable fibres mentioned in the instruction paper.

25. (a) What takes place when wool is boiled in solutions of various metallic salts? (b) Illustrate with the case of Aluminum Sulphate Solution.

26. Give composition of raw silk.

27. How does linen differ from cotton in composition?

28. Compare the average length of cotton, linen, wool and silk fibres.

29. (a) Describe the ordinary hydrometer. (b) Upon what fact is its utility based?

30. Give the object of the Hackling Process and its products.

31. (a) Define wool. (b) How are the different grades separated and what is the process called?

32. (a) How does jute differ from linen and cotton in composition? (b) How does jute act toward certain dyestuffs?

REVIEW QUESTIONS

ON THE SUBJECT OF

TEXTILE CHEMISTRY AND  
DYEING

PART II

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1. (a) Why is it necessary to give textile material a preliminary treatment before it is in a suitable condition for the processes of textile coloring and finishing?

(b) At what stages of the manufacturing process may this treatment be given?

2. (a) What is the object of cotton bleaching?

(b) What general principles are commonly involved in the process?

3. (a) What is the object of singeing cotton cloth?

(b) Describe the methods of carrying out the process.

4. (a) Give the approximate composition of raw cotton and explain the difference between the natural and foreign occurring impurities of cotton material.

(b) What is a back cloth?

5. (a) For what purposes is the madder bleach used, and how did it get its name?

(b) Give outline of the steps of the madder bleach.

6. (a) How is shearing accomplished?

(b) If you had to remove napp or fuzz from cloth after bleaching, would you singe or shear it? Explain your answer.

7. (a) What is a kier? (b) What are the common types, and how do they differ?

8. (a) Describe the brown sour. (b) Give the chemistry of the brown sour.

## TEXTILE CHEMISTRY AND DYEING

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9. Explain fully the chemistry and object of the lime boil.
10. (a) What are the common difficulties and irregularities met with in the working of a kier ?  
(b) What precautions may be taken to overcome these ?
11. (a) Describe the process known as the resin or rosin soap boil. (b) Explain the chemistry of the lye boil.
12. Explain the action of kiers illustrated in Figures 34 and 44.
13. Explain fully the theory of bleaching with chlorine and give reasons for the belief that this theory is true.
14. (a) Under what conditions is raw cotton bleached ?  
(b) How does the handling of raw or loose cotton in bleaching differ from that of yarn or cloth, and what precautions should be taken ?
15. (a) How does the Mather Steamer Kier Process differ from the Madder Bleach ? (b) Give outline of process and mention any advantages claimed for it.
16. (a) What is the object of the white sour ? (b) What can you say as to the relative values of hydrochloric and sulphuric acids for the souring process ?  
(c) Why is a wash given just before the white sour ?
17. Why is it necessary that the goods should be thoroughly washed at the end of the bleaching process ?
18. (a) Under what conditions should cotton yarn be bleached ? (b) Give outline of typical yarn bleaching process.
19. (a) What is bleaching powder ? (b) How is it made and what are its two possible formulæ ?
20. (a) Describe the method of preparing the bleaching bath when sodium peroxide is used.  
(b) Explain the chemistry of the process.
21. Describe briefly the common grades of bleaching other than the madder ?
22. (a) What is the object of chemicking ? (b) How is it accomplished ?



## REVIEW QUESTIONS

ON THE SUBJECT OF

### TEXTILE CHEMISTRY AND DYEING

#### PART III

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1. (a) Give general classification of dyestuffs.  
(b) Explain terms adjective, substantive, monogenetic, and polygenetic dyestuffs.
2. (a) Explain fully what is meant by a mordant.  
(b) What is the difference between a mordant and a mordanting principle?
3. (a) Explain the terms textile coloring, textile printing, and dyeing.  
(b) Explain the terms fixing agent and mordanting assistant.
4. (a) Give general method of applying mordants to wool.  
(b) Give general methods of applying mordants to cotton.  
(c) Why does the mordanting of wool differ from the mordanting of cotton?
5. (a) What metals act as mordants under certain conditions?  
(b) What particular compounds of these metals are usually the actual mordants?
6. (a) What are the common chromium mordanting principles?  
(b) Explain the use of potassium bichromate in wool mordanting.

## TEXTILE CHEMISTRY AND DYEING

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7. Give as many methods as you can for applying chromium mordants to wool.
8. (a) How may the natural dyestuffs be classified?  
(b) Give names of important dyestuffs of each class.
9. (a) What is indigo?  
(b) How is it obtained?  
(c) What are its sources?
10. (a) Explain the chemistry and principle of vat indigo dyeing, with equations.  
(b) How is the dyeing carried out?
11. (a) How is the woad vat set?  
(b) How is the hyposulphite vat set?
12. How does the dyeing of cotton with indigo differ from the dyeing of wool?
13. (a) What are indigo extracts?  
(b) How and for what are they used?
14. (a) What is logwood?  
(b) For what is it used?
15. (a) Explain three stages in development of coloring matter of logwood.  
(b) What connection is there between the above and logwood ageing?
16. How may logwood be applied to wool?
17. How may logwood be applied to cotton?
18. (a) What are the principal red natural dyestuffs?  
(b) What is madder, and why has it gone out of use?  
(c) How is cochineal applied to wool?
19. (a) What are the principal yellow natural dyestuffs?  
(b) For what is fustic used?
20. (a) For what is cutch used?  
(b) Give process of applying cutch to cotton.

## REVIEW QUESTIONS

ON THE SUBJECT OF

### TEXTILE CHEMISTRY AND DYEING

#### PART IV

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1. (a) How did the coloring materials of the older dyers differ from those used at the present time?

(b) Give an important classification of the artificial dyestuffs.

(c) Upon what is this classification based?

2. (a) Why are the basic colors so called?

(b) Why do the basic colors dye wool directly but not cotton?

(c) How can this lack of affinity between the basic colors and cotton be overcome?

3. (a) Give the essential difference between the process of dyeing wool and silk with basic colors, as compared with the application of the same dyestuffs to cotton.

(b) Give the characteristic properties of the basic colors.

(c) Name ten important basic colors.

4. What are the janus colors and why so called?

5. (a) What are the general characteristics of the phthalic anhydride colors and why are they so called?

(b) For what are the phthalic anhydride colors used and how are they applied to silk?

(c) Name some of the most important phthalic anhydride colors.

6. (a) Why are the acid colors so called?

(b) Into what three classes may the acid dyestuffs be divided, and upon what differences in composition is this classification based?

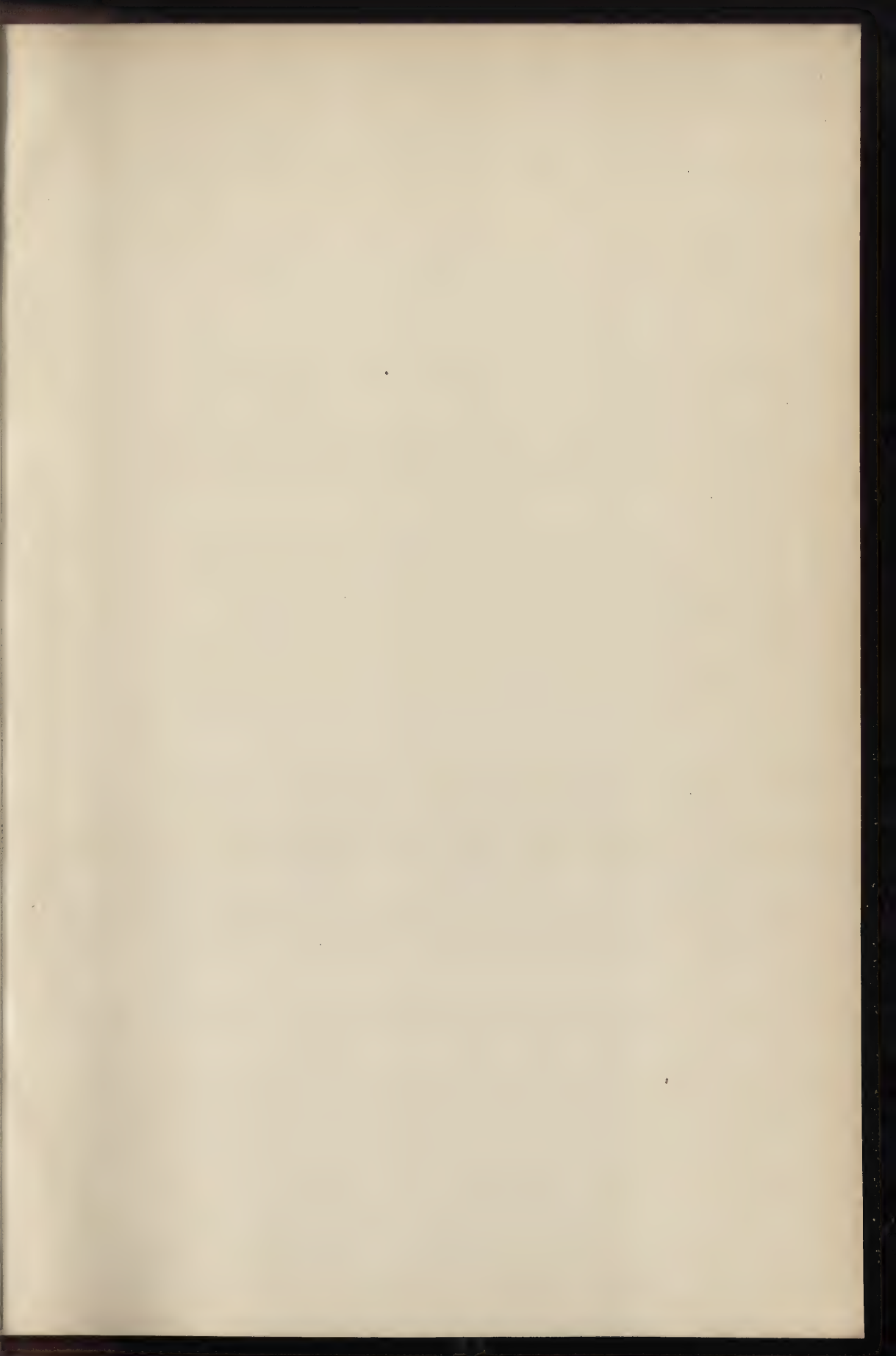
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# REVIEW QUESTIONS ON THE SUBJECT OF TEXTILE CALCULATIONS

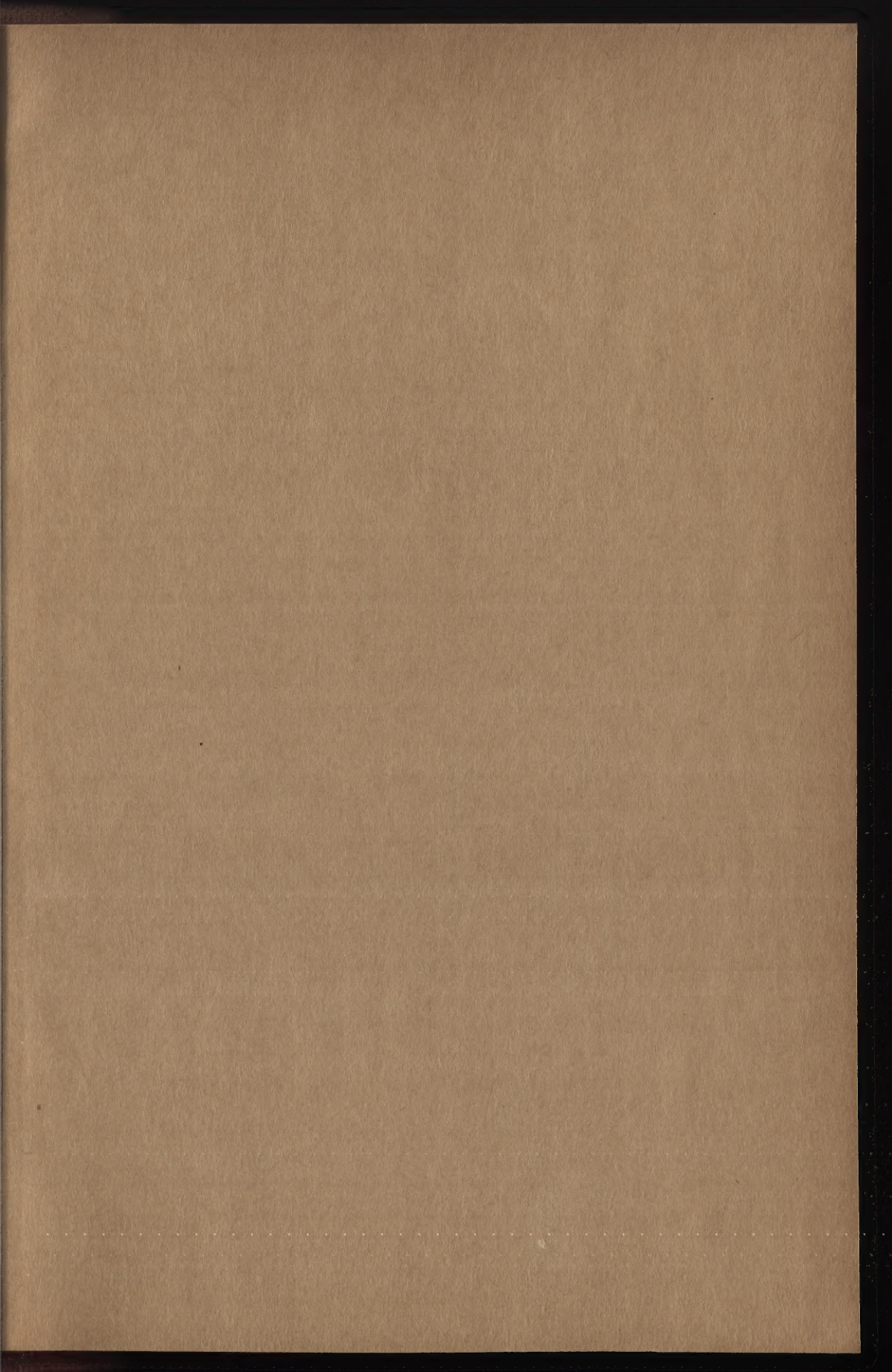
1. Find the worsted counts of the following yarns: 10,080 yards weigh 1 lb.; 9,240 yards weigh 12 ozs; 17,500 yards weigh  $1\frac{1}{4}$  lbs.
2. Find the woolen runs of the following yarns: 6,400 yards weigh 1 lb.; 2,100 yards weigh 4 ounces; 8,400 yards weigh  $5\frac{1}{4}$  lbs.
3. Find the cotton counts of the following yarns: 33,600 yards weigh 1 lb.; 20,160 yards weigh  $\frac{1}{2}$ -lb.; 100,800 yards weigh  $1\frac{1}{2}$  lbs.
4. What is the weight of 21,840 yards of 13's worsted yarn? 31,500 yards of 15's cotton yarn? 4,800 yards of 6-run woolen yarn? and 134,400 yards of 20's spun silk?
5. Change the following yarns to cotton counts: 60's worsted; 10-run woolen; and 14-lea linen.
6. Change the following yarns to worsted counts: 16's cotton; 7-run woolen; and 24's spun silk.
7. Give the metric counts of the following yarns: 28's worsted; 5-run-woolen; and 32's cotton.
8. Give the counts of the compound threads when the following yarns are twisted together: 36's and 30's worsted; 120's and 60's cotton; 30's and 60's spun silk.
9. Find the counts of a 3-ply thread composed of 60's, 30's, and 15's worsted; 72's, 36's, and 24's cotton; 12-run, 6-run, and 4-run woolen.
10. What is the counts of a novelty yarn composed of one thread each of 60's, 48's, and 36's cotton? The relative lengths of yarn used are 5, 4, and 2 inches. The 36's thread of which 2 inches are used is straight or 100%.

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